PERFORMANCE OF HYDRAULIC COAGULATION AND FLOCCULATION OF SG KAMPAR WATER TREATMENT PLANT

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Performance of Hydraulic Coagulation and Flocculation of Sg. Kampar Water Treatment Plant

by

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CERTIFICATION OF APPROVAL

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Approved by.

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources and persons.

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ABSTRACT

Coagulation and flocculation are based on the destabilization of colloidal particles. Chemical coagulant and aids are added into the water causing a reduction of force that tends to keep the particles apart. Thus causing colloidal particles to be destabilized and attached together. There are two types of flocculator which vary in terms of capability and economic consideration. These are mechanical and hydraulic flocculators. The former is commonly used in this country due to the economical factors and ease of maintenance. The objective of the study is to assess the influent of physical and other variables such as flow rate, temperature, dosage of alum and pH on the performance of hydraulic coagulation and flocculation of Sg. Kampar Water Treatment Plant. During the study, the mixing basin and flocculation tank design parameter were assessed. Calculation on power dissipation, velocity gradient, hydraulic retention time and Camp number for mixing basin and flocculation tank were made. Besides that, water samples at the inlet of mixing basin and outlet of flocculation tank were tested at laboratory. Parameters such as total suspended solid, turbidity, pH and colour were studied. Chemical dosages were studied based on jar test. Results indicated that the existing design and operation parameter used at Sg Kampar Water Treatment Plant are effective. Average velocity gradient and hydraulic retention time for mixing basin is 1056 sec^{-1} and 14.86 second respectively. As for the flocculation tank, the average velocity gradient and retention time are 26 sec^{-1} and 39 minutes respectively. Percentages removal of turbidity, colour and TSS are 19.8%, 23.1% and 13.7% respectively. As a conclusion, the study showed that the temperature and flow rate are not affected the performance of hydraulic coagulation and flocculation. However, pH of raw water and dosage of alum do have influenced on the performance of hydraulic coagulation and flocculation.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

WEF	Water Environment Federation
APHA	American Public Health Association
ASCE	American Society of Civil Engineers
MWA	Malaysian Water Association
AWWA	American Water Works Association
TSS	Total Suspended Solid
M	Mass of aggregates
D_f	Mass fractal dimension
R	Size of the aggregates
d	Floc diameter
C	Floc strength constant
G	Velocity gradient (s^{-1})
γ	Floc size exponent
g	Acceleration due to gravity (ms^{-2})
h_f	Head loss (m)
k	Kinetic energy (m^2s^{-2})
k_i, k_j	Turbulence kinetic energy at the same geometry point under nominal velocities V_i and V_j (m^2s^{-2})
K_a	Aggregation constant
K_b	Break-up constant (s)
K_p	Flocculator performance constant (cm^2s^{-1})
N	Number of control volume
N'	Number of channels
n_0, n_1	Concentration of primary particles at times 0 and t (NTU)
t	Elapsed time (s)
T	Theoretical retention time (s)
u', v', w'	Three dimensional velocity fluctuation (ms^{-1})
U_i, U_j	Nominal longitudinal velocities under condition i and j
u_i, u_j	Instantaneous velocities at the same geometry point under nominal velocities U_i and U_j
ρ	Water density (kgm^{-3})

μ	Dynamic viscosity ($kgm^{-1}s^{-1}$)
ν	Effective volume of flocculator (m^3)
ν_i	Control volume i (m^3)
L_i	Effective length (m)
Q	Flow rate (m^3s^{-1})
V	Volume (m^3)
μ	Water viscosity ($N.s/m^2$)
t_1	Turbidity for influent (NTU)/TSS for influent (mg/L)/Colour for influent (TCU)
t_2	Turbidity for effluent (NTU)/TSS for effluent (mg/L)/Colour for effluent (TCU)

CHAPTER 1

INTRODUCTION

1.1 Background Study

A study on water treatment plant is essential to determine the performance of the design parameters and operations processes. Designers should be fully aware of the performance of the plant. All water treatment plants can be improved and upgraded, both through design parameters and operations processes. Study and analysis on the water treatment plant is important to improve the performance of the plant.

1.1.1 Coagulation

Coagulation is defined as the destabilization of colloidal particles in water (Droste, 1997). According to MWA (1994), the purpose of coagulation is to prepare water for sedimentation and filtration at economically high rates of flow by agglomerating suspended particles and colloids into settleable floc.

Coagulation is a process that involves the formation of complex hydrous oxides to reduce the surface charge of colloidal particles. There are two phases involved in the coagulation process. First phase is choosing the proper chemicals, the proper dosages and the proper pH to achieve the micro-floc product (Hendricks, 2006). The second phase is causing contact between the coagulant chemicals and the colloidal particles (Hendricks, 2006).

The most common coagulants are alum ($Al_2(SO_4)_3$) and iron salts. Alum is the most extensively used coagulant in Malaysia. The effectiveness of the coagulation depends on the effective hydraulic mixing, optimum pH and proper dosage of coagulant.

1.1.2 Mixing and Power Dissipation

Coagulant and coagulant aids must be rapidly dispersed through the water body to ensure maximum and effective contact between the chemical reagent and suspended particles (Droste, 1997). Mixing is critical step that causing contact between reactant, creation of interfacial area and maximize the diffusion gradient across the interface area.

There are three phenomena that contribute to mixing; molecular diffusion, eddy diffusion and non uniform flow (Droste, 1997). Molecular diffusion is due to the thermally induced Brownian motion. Meanwhile, the latter two phenomena are functions of degree of turbulence.

1.1.3 Flocculation

Flocculation is defined as compacting and grouping of coagulated particles into larger particles called floc particles (Droste, 1997). Flocculation is a primary process in water treatment that changes the size of the particles from a large number of small particles to a small number of larger flocs.

Function of flocculation is to increase the number of contacts between coagulated particles suspended in water by gentle and prolonged agitation (MWA, 1994). Agitation results in collision of the fine particles for the formation of large floc. Larger floc can be easily settled in a sedimentation tank.

The major objective of flocculation is to cause a collision between the colloidal particles (Hendricks, 2006). After the collision, the smaller particles will stick to each other and agglomerate, growing into the desired size and becoming flocs. The agglomeration process is called flocculation. The effectiveness of flocculation depends on the coagulation process and design parameter of flocculation tank. Design parameter includes power dissipation, hydraulic velocity gradient and hydraulic retention time.

1.2 Problem Statement

Physical and chemical variables vary widely in all surface waters. Some of surface waters are difficult to treat because of high concentration of physical and chemical variables. Public water supply standard varies in each country in terms of the amount or concentration of variables permitted, depending on the water quality. In Malaysia, Malaysian Water Association has established to publish and set a standard for hydraulic coagulation and flocculation and other water treatment processes.

In practice, there are different kinds of mineral and suspended particles. These particles are found in waters and must be removed. The particles found in any ambient waters are unique to the environmental condition (e.g. geology, climate and ecology) and human activities (e.g. logging, mining, industrial activities). These factors influence the turbidity, total suspended solid, colour and alkalinity of the surface water.

Turbidity, surface water flow rate and particles count vary from place to place, seasonally and uniquely, depending on the environmental condition and human activities. In addition, water quality in Sg. Kampar changed regularly with season in the past two years. Thus, it is relevant to conduct a research at Sg. Kampar Water Treatment Plant to study the performance of the hydraulic coagulation and flocculation due to the changes of water quality and environmental conditions.

1.3 Objectives

Objectives of the study on the performance of hydraulic coagulation and flocculation at Sg. Kampar Water Treatment Plant are:

1. To study and analyse the design parameter of hydraulic mixing basin and flocculation tank.
2. To study the effect of water flow rate, temperature, pH of surface water and dosages of alum on the performance of hydraulic coagulation and flocculation.
3. To determine the percentage removal of total suspended solid, colour and turbidity to assess the performance of hydraulic coagulation and flocculation.

1.4 Scope of Works

The purpose of this study is to investigate the effects of surface water flow rate, pH, dosage of alum and temperature on the performance of hydraulic coagulation and flocculation at Sg. Kampar Water Treatment Plant. Performance of hydraulic coagulation and flocculation is measured in term of percentage removal of turbidity, colour and total suspended solid.

Main scope of this project is to investigate the suitability of mixing basin and flocculation tank design parameter such as power dissipation, hydraulic velocity gradient, hydraulic retention time and Camp number. All design parameter is calculated using Camp equation.

Meanwhile, the study on the performance of the water treatment plant required laboratory tests. Laboratory tests conducted are total suspended solid, turbidity, colour and jar tests. Samples of water for laboratory tests are taken at the inlet of the mixing basin and outlet of flocculation tank. Other parameters such as surface water flow rate, pH and temperature are taken directly from flow meter and pH meter at the water treatment plant. All data obtained are analyzed and validated.

CHAPTER 2

LITERATURE REVIEW

2.1 Coagulation Mechanisms

Coagulation process in water treatment plant is important to remove suspended particles in the raw water. Coagulation mechanism is based on combining the smaller and fine particles into larger and coarse particles. Generally, three mechanisms are involved in coagulation, i.e. charge neutralization, sweeping and bridging (Li et al, 2006).

Hydrolyzing metal is most widely used as coagulant. Li et al (2006) stated that the metal salts are hydrolyzed rapidly to form cationic species, which are absorbed by negative charge and caused charge reduction. Charge neutralization is a process where particles destabilized at low dosage of coagulant. Briefly, flocculation may occur due to the differential electrostatic charges on the different faces of primary particles (Liu et al, 2004). Sweep flocculation occurs when a metal salt is added to the water at sufficiently high concentration and cause a precipitation of amorphous metal hydroxide.

Moreover, the destabilization by bridging occurs when segments of a polymer chain absorb on more than single particle, thereby linking the particles together. As a consequence of bridging, the floc produced is much stronger than those formed by simple salt (Li et al, 2006).

Liu et al (2004) mentioned that the primary particles are typically of the order of 1-10μm in characteristic dimension. Flocculation could only occur if particles are brought into close proximity by the prevailing of hydraulic condition. There are several numbers of processes leading to the condition; i.e. Brownian motion, differential settling, kinetic and shear effects and inertial properties (Liu et al, 2004).

2.1.1 Physical Variables that Affect the Effectiveness of Coagulation

Effectiveness of coagulation has been measured by removal of turbidity, total suspended solid and sometimes colour (Hendricks, 2006). It is measured by comparing the raw water and filtering effluent. Turbidity and colour are most common physical variables that need to be addressed during treatment process. The levels of each parameter play large influences on the coagulation performance. It is important to have a reliable and consistent measurement throughout a year. It is clear that many water treatment plants are inefficient and difficult to operate, especially for the water of poor quality. Therefore, good and sufficient information are very important to provide more efficient production capacity in the future.

According to MWA (1994), the maximum turbidity level allowed in drinking water is 5 NTU. It also stated that the maximum acceptable raw water turbidity is 1000 mg/L. Standard for colour in drinking water is less than 15 TCU and the acceptable level for raw water is 300 TCU (MWA, 1994).

2.1.2 Chemical Variables that Affect the Effectiveness of Coagulation

The pH of the water indicates the degree of its alkalinity or acidity. The pH has significant influence on the reaction of the coagulants. Amount of coagulants such as $Al_2(SO_4)_3$ and $Fe_2(SO_4)_3$ are required to reduce water turbidity vary with pH of the water. Most water treatment plants are using alum due to economical consideration. According to Tebbutt (1998), the reactions which takes place when alum is added to water is complex and are often simplified as:

$$Al_2(SO_4)_3 + 6H_2O \longrightarrow 2Al(OH)_3 + 3H_2SO_4 \tag{2.1}$$

$$3H_2SO_4 + 3Ca(HCO_3)_2 \longrightarrow 3CaSO_4 + 6H_2CO_3 \tag{2.2}$$

$$6H_2CO_3 \longrightarrow 6CO_2 + 6H_2O \tag{2.3}$$

i.e. overall reaction is:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2 \qquad (2.4)$$

The optimum pH is particularly important so that no coagulants are wasted. According to MWA (1994), the optimum pH for coagulation of turbid water is within 5.7 to 6.5. Routine measurement of the pH should be made for raw water, settle water, filtered water and treated water. Samples should be taken in the distribution system to monitor any changes.

There are many factors that affect the success and effectiveness of particular coagulant, including mixing condition, pH, turbidity and temperature of the water. An effective floc will not form if the alkalinity of the water is not high enough. According to MWA (1994), any increases in turbidity, temperature and mixing energy will improve coagulation process. Common coagulant and doses are shown in Table 2.1.

Table 2.1 Common Coagulant and Doses (MWA, 1994)

Coagulant	Typical Dose Range (mg/L)
Aluminium Sulphate, $Al_2(SO_4)_3$	10 - 50
Ferric Sulphate, $Fe_2(SO_4)_3$	10 – 50
Ferrous Sulphate, $FeSO_4$	5 – 25

2.1.3 Fractal Dimension

Fractal dimension is defined as a statistical quantity which gives better an indication of how a fractal appears to fill space, as one zooms down to finer and finer scale. The fractal dimension measurement could not be derived accurately. Thus the measurement is based on estimation. Generally, the aggregates formed during coagulation exhibit fractal characteristic, imply that they are self-similar and scale invariant (Li et al, 2006). Fractal theory provides a new quantitative method to describe the particles of aggregates in water treatment plant. For an aggregate, the relation between mass (M) and size (R) is;

$$M \propto R^{D_f} \tag{2.5}$$

where:

M Mass of aggregates

R Size of the aggregates

D_f Mass fractal dimension

According to Li et al (2006), densely packed aggregates have a high fractal dimension, while large, highly branched and loosely bound structure results to lower fractal dimension. At the moment, three common techniques for fractal dimension measurement are light scattering, settling and image analysis.

2.1.4 Floc Strength

Li et al (2006) proposed that floc strength is another particularly important operational parameter that deserves special attention. However, the floc strength is dependent upon the bonding of the aggregates. The floc structure and particles bond strength are interrelated with floc strength (Li et al, 2006). When the stress on the floc surface is larger than the bonding stress, the structure of floc will break.

Although a number of methods have been developed, there is no straight forward technique to determine the characteristic of floc strength without destroying the floc. There is a limitation for investigating the floc structure and strength under different coagulation mechanisms. Commonly, jar test is conducted with focus on the relation between fractal dimension and strength of floc (Li et al 2006).

Researchers found a correlation between floc size and strength for a given rate of shear condition. The main objective of the investigation was to examine the morphological characteristic and strength of the floc formed under three different coagulation mechanisms and to understand the effect of different coagulation mechanism on floc structure and strength (Li et al, 2006).

According to Li et al (2006), relation between the stable floc size and applied shear force has been developed, with consideration of relationship between the velocity gradient in flocculation vessel and aggregates size. The relations are in terms of empirical expressions;

$$d = CG^{-\gamma} \tag{2.6}$$

$$\log d = \log C - \gamma \log G \tag{2.7}$$

where:

d	Floc diameter
C	Floc strength constant
G	Velocity gradient (s^{-1})
γ	Floc size exponent

2.2 In Situ Analysis of Flocs

Chakraborti et al (2007) defined suspended solid present as flocs, aggregates and clusters of particles both in natural and engineered environment. The growth of the aggregates depends on the physical, biological and chemical conditions. The particles growth depends on the density, surface charge, roughness and local shear force. In situ measurement is a particular process to analyse suspended particles (Chakraborti et al, 2007).

In conventional aggregation model, particles are assumed to be compact spheres. Other features such as particles and hydrodynamic inter action are explored on the basic of spherical particles (Chakraborti et al, 2007). Density of the aggregates is defined as the total mass of aggregates divided by its volume. Density of aggregates is assumed constant and equal to the density of the initial primary particles that formed the aggregate (Chakraborti et al, 2007).

Mathematical modeling is used to simulate particles and sediment remediation strategies. It is difficult to assess the actual properties of flocs. Therefore, a spherical and discrete approach, with some assumption is used in these analyses even though further studies have been reported that the natural suspended particles are not spherical.

Various measurement methods are explored to find a suitable method to analyze floc structures without disturbing fragile floc structure and to preserve natural process of floc formation. A complete non-intrusive imaging method was used. This is because the method avoids potential problems associated with the sample collection and handling. Chakraborti et al (2007) documented the development of an imaging method as a suitable method for estimating fractal dimension of suspended aggregates.

The imaging method is based on the real aggregate structure as represented by fractal geometry. This type of measurement can be used to answer floc physical properties that influence transport behavior in suspension (Chakraborti et al, 2007). It is expected that this imaging method will enhance our capability to model aggregate interaction and transport.

2.3 Design of Mixing Basin

Coagulant may be applied at any point where the turbulence is high. There are variety of hydraulic devices such as weir and flume. Weir can be used as flow measurement. There are some factors that affect the performance of hydraulic mixing. One of the factors is hydraulic head loss for hydraulic device. Recommended hydraulic head loss is at least 0.6 m (Droste, 1997). This is very important to ensure good mixing. The AWWA and ASCE (1990) recommend that a volume equivalent to 2 sec retention time to be used when mixing takes place in a pipe or open channel with a velocity greater than 0.5 m/s. The entire volume of the conduit should be used if the velocity lower than 0.5 m/s or the possibility of backflow eddies exists (Droste, 1997).

Since coagulation reactions are rapid, a short retention time is necessary and high degree of turbulence is required. Criteria value for effective mixing as suggested by Sincero (2003) is shown in Table 2.2 below. The standard expression for velocity gradient, G is;

$$G = \sqrt{\frac{P}{V\mu}} \tag{2.8}$$

where:

G	Velocity gradient (s^{-1})
P	Power dissipated in fluid motion (N.m/sec)
μ	Dynamic viscosity ($kgm^{-1}s^{-1}$)
V	Volume (m^3)

Table 2.2 Criteria Value for Effective Mixing (Sincero, 2003)

Retention Time, (s)	Velocity Gradient (s^{-1})
<10	4000-1500
10-20	1500-950
20-30	950-850
30-40	850-750
40-130	750-700

2.4 Design of Hydraulic Flocculation Tank

Velocity difference in all flowing and stirred water brought the suspended particles into contact. Velocity gradients occur from point to point. Velocity gradients are induced by hydraulic and mechanical means. The common hydraulic flocculation is the baffle tank while the common mechanical device for flocculation is the paddle type.

According to McConnachie et al (1999), hydraulic flocculation has been used for many years. Design of the hydraulic flocculation is usually specified by the intensity of energy dissipation, hydraulic velocity gradient, hydraulic retention time and the resultant Camp number, GT (McConnachie et al, 1999). The equation for hydraulic velocity gradient is similar to Equation 2.8.

The basic principle in the design of flocculation tank was published by Camp, whereby the total number of particles collision is proportional to 'GT'. Thus, the rate of floc formation is directly proportional to G; the larger the G value, the shorter the time required. However, very large value of G will result in excessive shearing force. This may, in fact, tend to shear floc particles, where, as the floc becomes larger, it will become weaker.

For the work done by the flowing water in the flocculation tank where hydraulic head loss involved, the expression is;

$$P = Q\rho g h_f \tag{2.9}$$

where:

P	Power dissipation (N.m/s)
ρ	Water density (kgm^{-3})
g	Acceleration due to gravity (ms^{-2})
Q	Flow rate (m^3s^{-1})
h_f	Head loss (m)

The standard for the value for G as suggested by Fair and Geyer (1954) is within range of 100-10 s^{-1}. Meanwhile the GT should be within of 10^4 to 10^5. There are advantages and disadvantages using hydraulic flocculator in water treatment plant. The advantages include good performance if the flow rate is reasonable constant, minimal maintenance due to the lack of electro-mechanical equipment and short-circuiting (McConnachie et al, 1999). Disadvantages are lack of flexibility for coagulant mixing intensity, possible cleaning difficulties and high hydraulic head loss for over and under baffles systems (McConnachie et al, 1999).

McConnachie et al (1999) stated that the disadvantage of flexibility for mixing intensity is due to large seasonal variation especially for tropical river waters.

Particles of water need to collide to form floc and this depends on the particle concentration which likely to have large seasonal variation (McConnachie et al, 1999). McConnachie et al (1999) also suggested that adjustment for turbulence levels required can be effected by removing and inserting grid baffles through the flow passes.

According to MWA (1994), value for hydraulic velocity gradient is usually in the range of 12.5 to 30 s-1, with hydraulic retention times varying from about 15 to 40 minutes. The value for Camp number, GT is in the range of 11,250 to 72,000 (MWA, 1994). Meanwhile, the criteria for effective flocculation as suggested by Sincero (2003) are in Table 2.3 below.

Table 2.3 Criteria Value for Effective Flocculation (Sincero, 2003)

Type of Raw Water	G (s^{-1})	GT
Low Turbidity and Colored	20-70	50000-250000
High Turbidity	70-150	80000-190000

2.4.1 Typical Baffle Walls Design

Baffle walls are used to equalize flow distribution. Design guidelines for baffle walls (also known as diffuser walls) vary among various sources (AWWA and ASCE, 1990). The area of the baffle orifices is approximately 3-6% of the wall area or provides a velocity of 0.3 m/s under maximum flow condition (AWWA and ASCE, 1990). The size of an orifice should be between 40 and 175 cm^2. The baffle wall is raised 1.25 to 4 cm above the floor to allow easy cleaning of sludge deposits.

2.5 Advanced Design of Channel Hydraulic Flocculator

Design procedure for hydraulic flocculator relies on the simple calculation, using values related to the overall turbulence in the whole flocculator (Liu et al, 2004). Traditional calculation based on average is not really suitable for flocculator design as the hydraulic condition is innately heterogeneous. Furthermore, the availability of CFD software renders more accurate calculation and simulation (Liu et al, 2004).

2.5.1 Average G Method

Average G method is due to the work of previous researcher, who considered the effects of particles aggregation and floc break-up in mechanical flocculator. According to Liu et al (2004), there are three constants quantifying floc formation (K_a), floc break-up (K_b) and flocculate performance (K_p) as a simplified method which taking account of the complex issues of flocculation, leading to the expressions;

a) Average G method for continually stirred-tank rector

$$\frac{n_1}{n_0} = \frac{1 + K_b G^2 t}{1 + K_a G^2 t} \tag{2.10}$$

b) Average G method for plug flow reactor

$$\frac{n_1}{n_0} = \frac{K_b}{K_a} G + \left(1 - \frac{K_b}{K_a} G\right) e^{-K_a G t} \tag{2.11}$$

where:

n_0, n_1	Concentration of primary particles at times 0 and t (NTU)
K_a	Aggregation constant
K_b	Break-up constant (s)
G	Velocity gradient (s^{-1})
t	Elapsed time (s)

2.5.2 Point-to-Point Method

An alternative method to the average G method is point-to-point method where it is used to consider a flocculator as a number of discrete volumes (Liu et al, 2004). This represents the actual physical subdivision of the flocculator. Designers shall consider each discrete volume separately and use actual retention time and turbulence instead of overall G parameter for design process (Liu et al, 2004). The result for each discrete volume can be summed to give an overall performance for the whole flocculator. Liu et al (2004) described this method as more accurate than the other method. It does actually need velocity and turbulent kinetic information to determine each of the discrete volume. Since plug flow condition is applicable, the Eq. 2.11 is used and the result is shown below;

$$\frac{n_1}{n_0} = \frac{K_b}{K_a}\sum_{i=1}^{N}\frac{\left(\frac{2}{K_p}\right)k_i\forall_i}{\forall} + \left(1 - \frac{K_b}{K_a}\sum_{i=1}^{N}\frac{\left(\frac{2}{K_p}\right)k_i\forall_i}{\forall}\right)e^{x} \tag{2.12}$$

$$x = -K_a\sum_{i=1}^{N}\frac{\left(\frac{2}{K_p}\right)k_i\forall_i}{\forall\frac{L_i}{u_i}} \tag{2.13}$$

$$k_i = 0.5\left(u'^2_i + v'^2_i + w'^2_i\right) \tag{2.14}$$

where:

n_0, n_1	Concentration of primary particles at times 0 and t (NTU)
K_a	Aggregation constant
K_b	Break-up constant (s)
K_p	Flocculator performance constant (cm^2s^{-1})
N	Number of control volume
L_i	Effective length (m)
V	Volume (m^3)
u', v', w'	Three dimensional velocity fluctuation (ms^{-1})

Current state of art on the performance of hydraulic coagulation and flocculation as done by other researchers only emphasized on the coagulation mechanisms and design of flocculation tank. All the study involving the coagulation is done in the laboratory and under control environment. Study on the coagulation mechanism including floc strength, fractal dimension, physical variables that affect the coagulation and chemical reaction during the coagulation.

Beside that, there are seldom researchers do a study on the performance of actual water treatment plant. As discussed earlier, performance of water treatment is unique. This is because of the different water quality. Water quality is unique depends on the environmental condition and human activities. Thus, it is appropriate to carry out a study on the performance of hydraulic coagulation and flocculation of Sg. Kampar Water Treatment Plant.

CHAPTER 3
METHODOLOGY

The methodology shall be in accordance with the defined methods as prescribed by the American Water Work Association (AWWA), American Public Health Association (APHA) and Water Environment Federation (WEF). However, the selection of the parameters to be monitored shall be relevant to the study. Data and result should represent the water quality through out the hydraulic coagulation and flocculation system.

3.1 Water Treatment Plant Description

Sungai Kampar Water Treatment Plant is situated at the bank of Sg. Kampar, near Kuala Dipang, Perak. It was commissioned over 40 years ago. The design production is 8 MGD with an average production of 3.6 MGD. Treated water is pumped to the two reservoirs nearby. Capacity for Reservoir 1 is 500,000 gallon and Reservoir 2 is 2 million gallon. Raw water source is from Sg. Kampar and Sg. Dipang. Raw water is pumped to the water treatment plant from an intake which is at a distance of approximately 130 m. Catchment area is made up of ex-mining land, agricultural areas, forest reserved beside a number of aboriginal settlements and Malay reservation areas. Treated water is supplied to 14,000 premises at Malim Nawar, Kpg Jeram, Kuala Dipang and a number of rural areas in Gopeng.

3.2 Flow Rate, pH and Temperature Measurement

Flow rate, pH and temperature for raw water are taken directly at the water treatment plant. The readings for flow rate, pH and temperature are taken from the flow meter and pH meter which are installed at the plant. Flow rate is expressed in volume per hour (m^3/h).

Figure 3.1 Flow Meter

Figure 3.2 pH and Temperature Meter

3.3 Water Sampling and Procedures

Samples are taken from Sg. Kampar Water Treatment Plant once in every hour for 31 days. Samples are taken from time to time under different raw water characteristics and weather. Samples of water are collected from the inlet of mixing basin and outlet of flocculation tank.

Samples are collected in plastic bottles with appropriate care. Water samples are taken using appropriate sampling device such as glass. Sampling and transport process are handled properly in order to prevent contamination or change in composition. Sufficient volumes of samples are taken for laboratory analysis. The sample bottles are sealed and remain so until they are opened for analysis in the laboratory. The water samples are placed in sturdy boxes for transportation. Any possibilities of contamination to the boxes and samples are to be avoided. The samples should reach laboratory as soon as possible within 24 hours for analysis.

3.4 Design Parameter Evaluation for Mixing Basin and Flocculation Tank

Design parameters such as the size and dimension of the mixing basin and flocculation tank are measured. The measurement for the dimension of the mixing basin and the flocculation tank such as length, width and depth is done using measuring tape. The measurement is recorded for further analysis. The manual measurement is then compared with the dimension from blue prints or as-built drawings of the mixing basin and flocculation tank. The blue prints or as-built drawings are obtained from Lembaga Air Perak (LAP).

3.4.1 Mixing Power for Mixing Basin and Power Dissipation for Flocculation Tank

To determine the mixing power of the mixing basin and the flocculation tank, some variables such as hydraulic head loss and water surface flow rate need to be determined. These variables influence the power dissipation, hydraulic velocity gradient and hydraulic retention time for the mixing basin and the flocculation tank.

Surface water flow rates at inlet of the mixing basin and outlet of the flocculation tank are taken directly from the flow meter at the water treatment plant. Hydraulic head loss at the mixing basin and flocculation tank is measured by using the measuring tape.

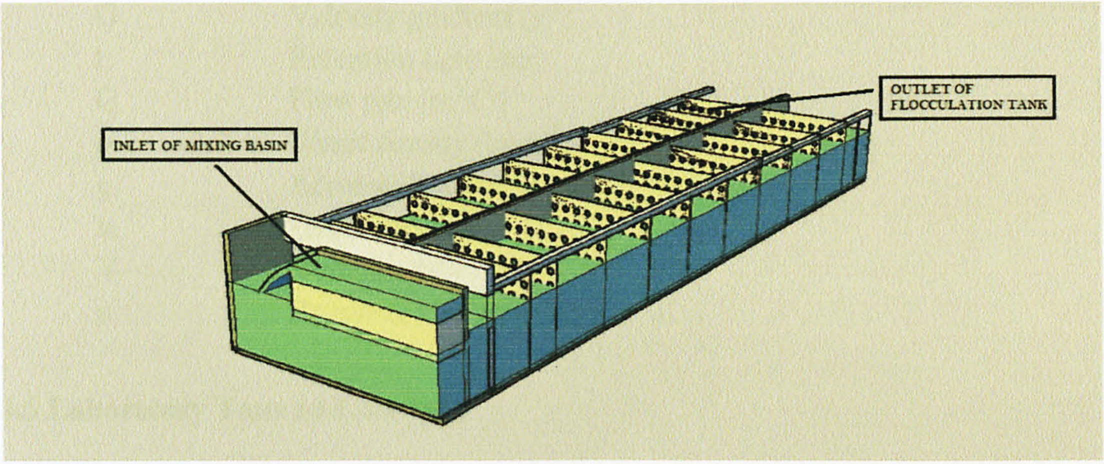

Figure 3.3 Mixing Basin and Flocculation Tank Model

3.4.2 Mixing Basin and Flocculation Tank Design Analysis

Mixing power and power dissipation calculation are based on the simple hydraulic equations. The equations used for the calculation are;

1. Power Dissipation, P;

$$P = Q\rho g h_f \tag{3.1}$$

2. Hydraulic Velocity Gradient, G;

$$G = \sqrt{\frac{P}{V\mu}} \tag{3.2}$$

3. Hydraulic Retention time, t;

$$t = \frac{V}{Q} \tag{3.3}$$

where:

P	Power dissipation (Nm/s)
G	Velocity gradient (s^{-1})
t	Retention time (sec)
Q	Flow rate (m^3s^{-1})
ρ	Water density (kgm^{-3})
g	Acceleration due to gravity (ms^{-2})
h_f	Head loss (m)
V	Volume (m^3)
μ	Dynamic viscosity ($kgm^{-1}s^{-1}$)

3.5 Laboratory Tests and Analysis

To evaluate the performance of the hydraulic coagulation and flocculation, a number of laboratory tests have been conducted. Laboratory tests that have been conducted are turbidity, colour, pH, total suspended solid and jar tests. The samples of water are attended immediately after collected. All samples are analysed as soon as possible. The physical parameters, such as pH, turbidity and colour are measured at the water treatment plant. Meanwhile, the other parameter such as total suspended solid is measured immediately at UTP laboratory within 72 hours after collection.

All laboratory tests are using the methods recommended in the Standard Methods for Examination of Water and Wastewater published by American Public Health Association, American Water Works Association and Water Environment

Federation (2005). Turbidity of the samples is measured using Hach 2100P Turbidimeter. Meanwhile, colour is measured using Hach Palintest 8000.

Figure 3.4 Hach 2100P Turbidimeter

Figure 3.5 Hach Palintest 8000

3.6 Data Analysis and Validation

Performance of the hydraulic coagulation and flocculation has been measured traditionally by the removal of the turbidity, colour and total suspended solid of the water. Calculation of the percentage removal of the turbidity, colour and total suspended solid of the water is in the terms of comparing flocculation effluent with mixing basin influent. Calculation to determine the percentage removal of the turbidity, colour and total suspended solid is shown in Equation 3.4 below;

$$Percentage\ removal\ (\%) = \frac{t_1 - t_2}{t_1} \times 100\% \qquad (3.4)$$

where:

t_1	Turbidity for influent (NTU)/TSS for influent (mg/L)/Colour for influent (TCU)
t_2	Turbidity for effluent (NTU)/TSS for effluent (mg/L))/Colour for effluent (TCU)

The methodology for this study on the performance of hydraulic coagulation and flocculation process of Sg. Kampar Water Treatment Plant is shown in Figure 3.6 below.

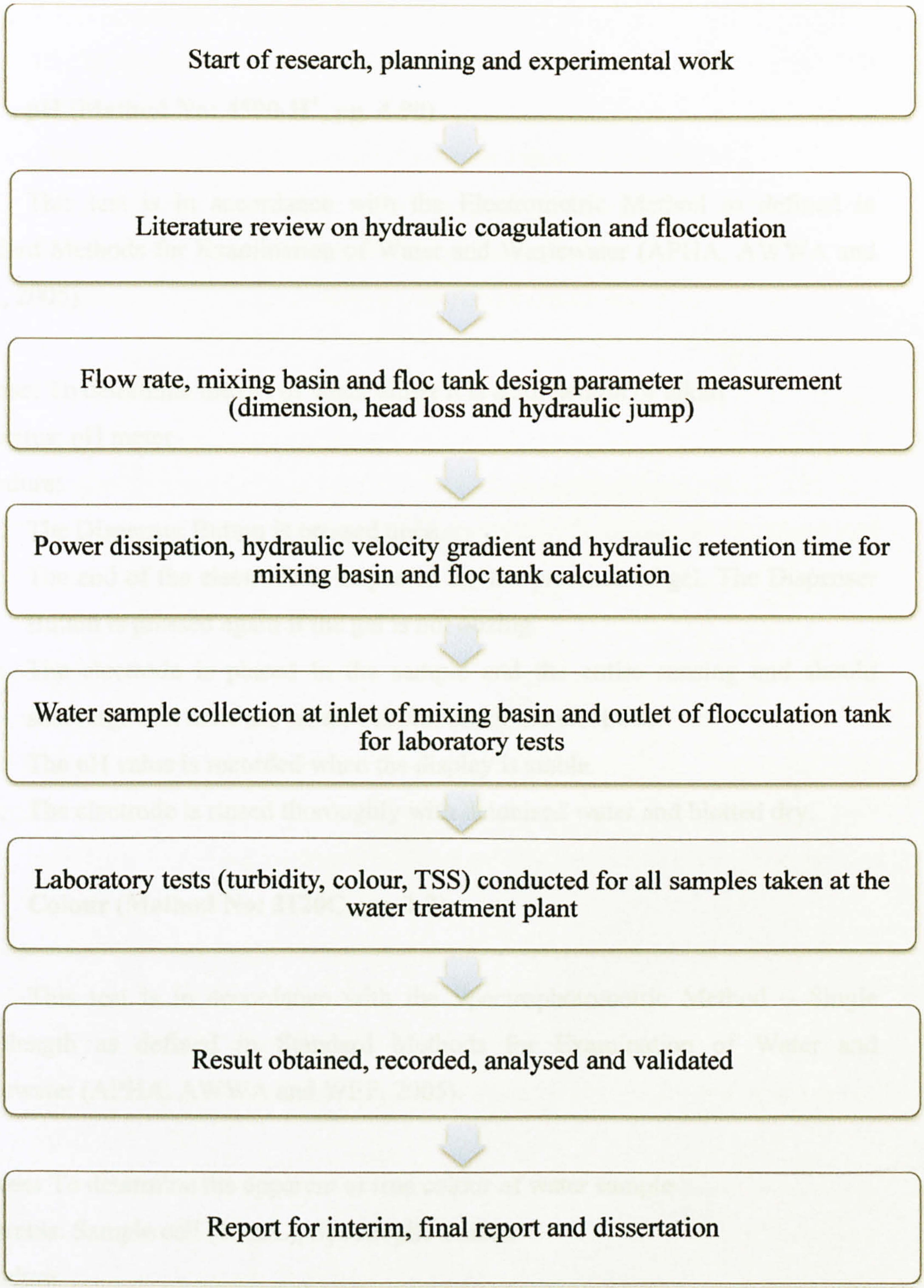

Figure 3.6 Methodology Flow Chart

3.7 Experimental Set-Up and Procedures

The laboratory method and set up is in accordance with the Standard Methods for Examination of Water and Wastewater (APHA, AWWA and WEF, 2005).

3.7.1 pH (Method No: 4500-H^+, pg. 4-90)

This test is in accordance with the Electrometric Method as defined in Standard Methods for Examination of Water and Wastewater (APHA, AWWA and WEF, 2005).

Purpose: To determine the pH of water either it is acid, neutral or alkali
Apparatus: pH meter
Procedure:

1. The Dispenser Button is pressed once.
2. The end of the electrode is inspected for the presence of gel. The Dispenser Button is pressed again if the gel is not oozing.
3. The electrode is placed in the sample and the entire sensing end should submerge and there are no air bubbles under the electrode.
4. The pH value is recorded when the display is stable.
5. The electrode is rinsed thoroughly with deionised water and blotted dry.

3.7.2 Colour (Method No: 2120C, pg. 2-3)

This test is in accordance with the Spectrophotometric Method – Single Wavelength as defined in Standard Methods for Examination of Water and Wastewater (APHA, AWWA and WEF, 2005).

Purpose: To determine the apparent or true colour of water sample
Apparatus: Sample cell (10 mL), Spectrophotometer
Procedure:

1. The filtering apparatus is assembled.

2. The filter is rinsed by pouring about 50 mL of distilled water through the filter. The rinse water is discarded.
3. Another 50 mL of distilled water is poured through the filter.
4. Blank preparation: A sample cell is filled with distilled water.
5. Prepared sample: Fill a second sample cell with 10 mL of the water sample.
6. The blank sample cell is wiped and inserted into the cell holder with the fill line facing right.
7. ZERO Button is pressed and the display will show: 0 units PtCo.
8. The prepared sample cell is wiped and inserted into the cell holder with the fill line facing right. READ Button is pressed.
9. The result display on the spectrophotometer is recorded.

3.7.3 Total Suspended Solid (Method No: 2540D, pg. 2-58)

This test is in accordance with the Total Suspended Solid Dried at 103 °C - 105 °C Method as defined in Standard Methods for Examination of Water and Wastewater (APHA, AWWA and WEF, 2005).

Purpose: To calculate the non-filterable residue in water using gravimetric method
Apparatus: 45µm Filter paper, Filter holder, Filtering flask, Measuring cylinder (1000 mL), Watch glass, Drying oven, Desiccators, Tweezers
Procedure:

1. A 47 µm filter disc is placed in the filter holder with the wrinkled surface upward.

Note: Always use a tweezers to handle filter discs. Fingers and moisture will subsequently cause a weighing error.

2. A 100 ml of well-mixed, representative water sample is filtered by applying vacuum to the flask. This is followed by three separate 10ml washings of deionised water.

Note: For greatest accuracy, as much sample as possible should be filtered. However, using a sample more than 15 mg of solids will result in premature plugging of water sample and may have to be adjusted (increased or decreased) to achieve this optimum condition. Several complete tests will show whether any adjustment is necessary.

3. The vacuum is slowly released from the filtering system and the filter is gently removed from the holder. The disc is placed on a watch glass. The filtrate is inspected to ensure the proper trapping of solids was accomplished on the disc.

Note: Be sure to remove any residue adhering to the sides or bottom lip of the filter holder. A rubber policeman on the end of a string rod is very helpful in scrapping this residue loose, and small amount of deionised water will help to wash the residue down the filter disc.

4. The watch glass and filter is again placed in a drying oven at 103 °C for 1 hour.
5. The watch glass and filter is removed from the oven, and carefully place in a desiccators. Allow to cool to room temperature.
6. The disc is carefully removed from the desiccators and weighed to the nearest 0.1 mg using analytical balance.

Note: Take extreme care when removing the lid of the desiccators as to not disturb the dried suspended matter on the disc. Remove the watch glass and disc from the desiccators as a unit and place beside the analytical balance. Use plastic tweezers to transfer the disc to and from the weighing pan on the balance.

Figure 3.7 Total Suspended Solid Apparatus

3.7.4 Turbidity (Method No: 2130B, pg. 2-9)

This test is in accordance with the Nephelometric Method as defined in Standard Methods for Examination of Water and Wastewater (APHA, AWWA and WEF, 2005).

Purpose: To determine the turbidity of water sample

Apparatus: Sample cell with cap, Turbidimeter

Procedure:

1. A representative sample is collected in a clean container.
2. A sample cell is filled to the line (about 15 mL) by taking care to handle the sample cell by the top.
3. The sample cell is wiped softly with a lint-free cloth to remove water spot and fingerprint.
4. The sample cell is placed in the Turbidimeter and the reading is taken and recorded.

3.7.5 Jar Test

This test is in accordance with the Jar Test as defined in Standard Methods for Examination of Water and Wastewater (APHA, AWWA and WEF, 2005).

Purpose: To determine the optimum dosage of alum

Apparatus: Six paddles jar test apparatus, Six 1-L beakers, Six 100-mL beakers, Two 10-mL graduated pipettes, Six 50-mL pipettes, Turbidimeter, pH meter

Procedure:

1. 10 g/L stock alum is prepared by dissolving 10.0 g of $Al_2(SO_4)_3 16H_2O$ into 1000 ml of distilled water.
2. Turbidity and pH of the water sample is measured.
3. 1000 ml of the water sample is filled in six 1-L jars.
4. The jars are placed under the paddles of the jar test apparatus and the paddles are lowered to the same depth in each jar.
5. Rapid mix is started at 100 rpm.
6. Alum dosage is set as shown in Table 3.1:
7. Rapid mix is continued for 1 min and followed by slow mix at 30 rpm at 20 min.
8. Flocculation (floc formation) is observed in each jar during the mixing and recorded as good, fair or poor.
9. The stirrers are turned off at the end of 20 min to allow settling for 30 min.

10. 50 mL supernatant sample from each jar is withdrew and placed in the 100 mL beakers.
11. The turbidity and pH of the supernatant samples is measured.
12. Supernatant turbidity and pH versus alum dose is plotted.
13. The lowest alum dose for supernatant turbidity is determined as it is the optimum alum dose for effective coagulation-flocculation of the water.

Table 3.1 Alum dosage

Jar No.	Volume of Stock Alum Solution, mL	Alum Dose, mg/L
1	0	0
2	1.0	10
3	2.0	20
4	3.0	30
5	4.0	40
6	5.0	50

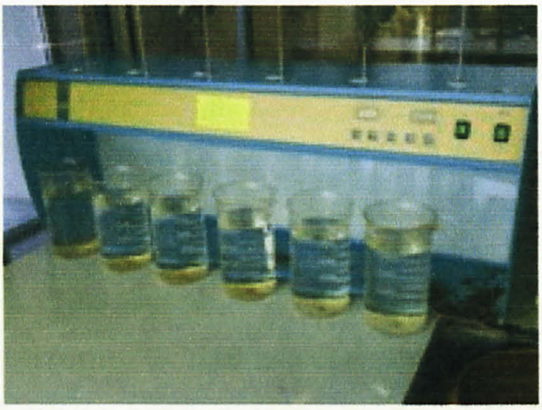

Figure 3.8 Jar Test Apparatus

CHAPTER 4
RESULT AND DISCUSSION

4.1 Design Parameters for Mixing Basin and Flocculation Tank

A summary of the measurements, inputs and results of design parameter for mixing basin and flocculation tank are given in Figures 4.1, 4.2 and 4.3. As mentioned before, the design of mixing basin and flocculation tank depends on power dissipation, velocity gradient, retention time and Camp number, Gt. For this study, there are two main variables that affect all these parameters. These two variables are water flow rate and hydraulic head loss. Theoretically, power dissipation and hydraulic velocity gradient increases proportionally with water flow rate under the same hydraulic head loss. Meanwhile, the hydraulic retention time inversely proportional with water flow rate.

4.1.1 Power Dissipation

Figure 4.1 shows the relation between power dissipation and water flow rate. During the study period, the maximum flow rate recorded is 1534 m^3/h and the minimum flow rate is 1370 m^3/h. The average flow rate recorded is 1418 m^3/h. Power dissipation for mixing basin is within the range of 2272 N.m/s and 3103 N.m/s. The mean power dissipation for mixing basin is 2935 N.m/s. From the graph, it can be seen that the power dissipations for mixing basin increase as flow rate increases. Hydraulic head loss recorded during the study period for mixing basin is 0.76 m. The recommended hydraulic head loss for effective mixing is at least 0.6 m (Ronald L Droste). The hydraulic head loss for mixing basin of Sg. Kampar Water Treatment Plant is considered satisfactory.

For flocculation tank, the power dissipations varied between 525 N.m/s to 588 N.m/s. Average power dissipation for flocculation tank is 556 N.m/s. From the graph, it can be seen that the power dissipations for flocculation tank do not have large variation as mixing basin. This is due to small variation of flow rate and hydraulic head loss. For flocculation tank, the hydraulic head loss is 0.144 m.

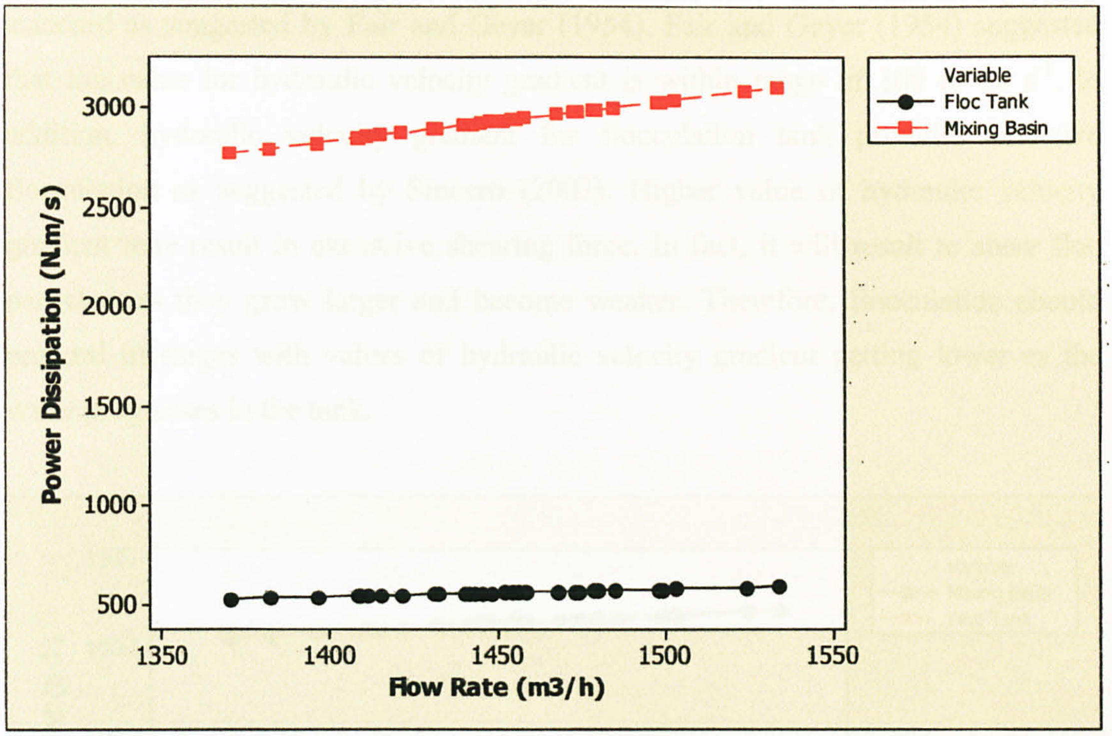

Figure 4.1 Power Dissipation vs. Flow Rate

4.1.2 Velocity Gradient

Figure 4.2 shows relation between hydraulic velocity gradient and flow rate. Hydraulic velocity gradient for mixing basin varied between 1026 sec^{-1} and 1085 sec^{-1}. An average hydraulic velocity gradient for mixing basin is 1056 sec^{-1}. For mixing basin, the hydraulic velocity gradient increases with flow rate. This is proved by the theory that stated the hydraulic velocity gradient increases proportionally with flow rate.

Hydraulic velocity gradients in the flocculation tank are within 25 sec^{-1} and 27 sec^{-1}. An average hydraulic velocity gradient for flocculation tank during the study period was 26 sec^{-1}. From the graph, it can be seen that the hydraulic velocity gradients are slightly constant and has no significant variation. According to MWA (1994), hydraulic velocity gradient for flocculation tank is usually in the range of 30 to 12.5 sec^{-1}. Thus, the hydraulic velocity gradient for flocculation tank is within the MWA (1994) design guideline.

The hydraulic velocity gradient for flocculation tank also satisfied the standard as suggested by Fair and Geyer (1954). Fair and Geyer (1954) suggested that the value for hydraulic velocity gradient is within range of 100 to 10 s^{-1}. In addition, hydraulic velocity gradient for flocculation tank provides effective flocculation as suggested by Sincero (2003). Higher value of hydraulic velocity gradient may result in excessive shearing force. In fact, it will result to shear floc particles, as they grow larger and become weaker. Therefore, flocculation should proceed in stages with values of hydraulic velocity gradient getting lower as the water progresses in the tank.

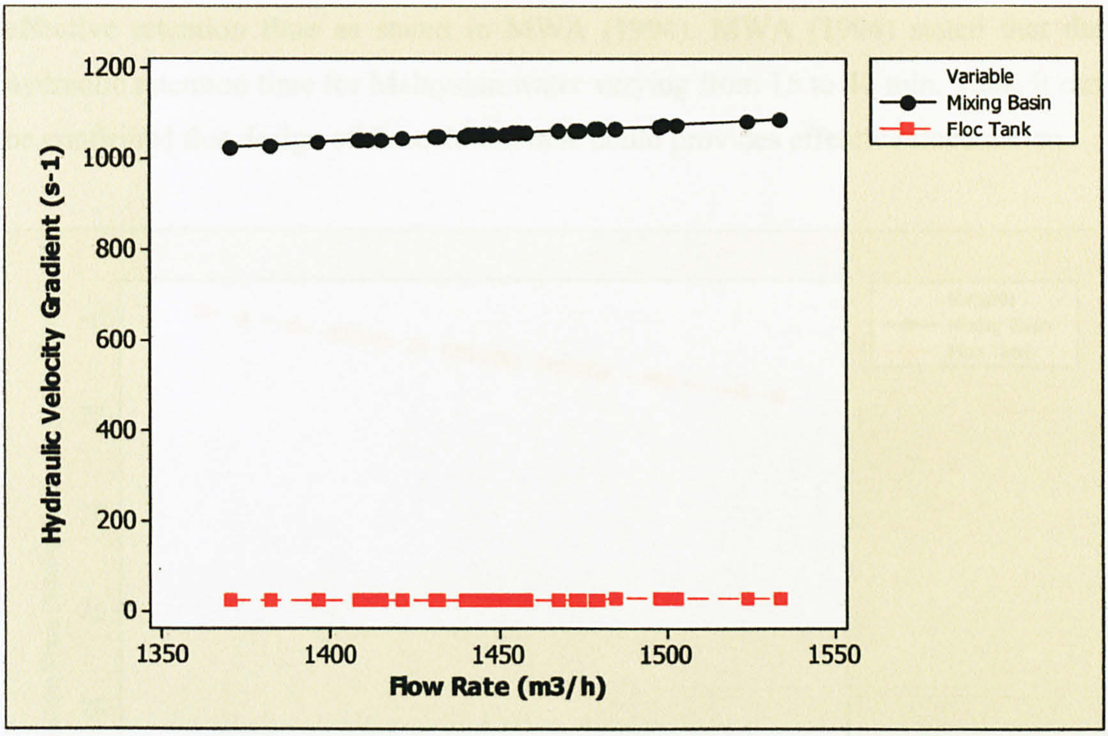

Figure 4.2 Hydraulic Velocity Gradients vs. Flow Rate

4.1.3 Hydraulic Retention Time

Figure 4.3 shows a relation between flow rate and hydraulic retention time for both mixing basin and flocculation tank. Minimum hydraulic retention time recorded during study period is 14 sec for mixing basin and 36.11 min for flocculation tank. Maximum hydraulic retention time is 15.72 sec for mixing basin and 40.44 min for flocculation tank. Average retention time is 14.86 sec and 39 min for mixing basin and flocculation tank respectively.

According to Sincero (2003), hydraulic retention time for effective mixing is within the range of 10 to 20 sec and hydraulic velocity gradient is within the range of 1500 to 950 s^{-1}. So it can be confirmed that design for mixing basin could provides effective mixing.

Meanwhile, hydraulic retention time for flocculation tank is within the effective retention time as stated in MWA (1994). MWA (1994) stated that the hydraulic retention time for Malaysian water varying from 15 to 40 min. Thus, it can be confirmed that design of flocculation tank could provides effective flocculation.

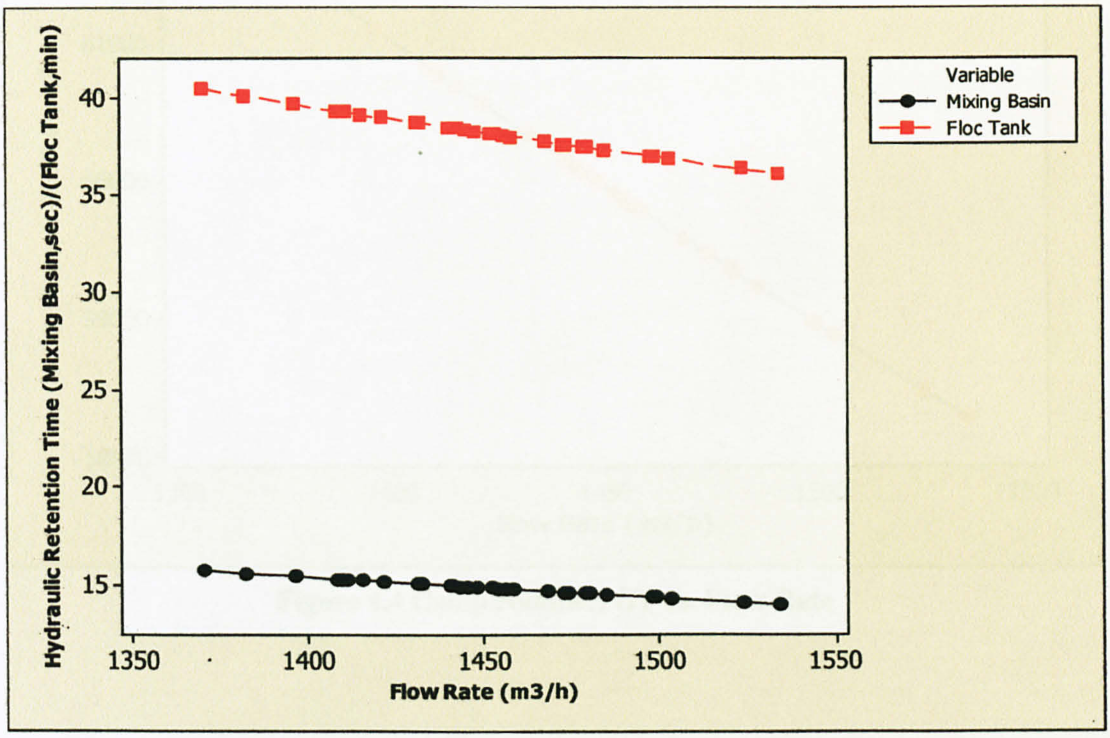

Figure 4.3 Hydraulic Retention Time vs. Flow Rate

4.1.4 Camp's Number, GT

According to MWA (1994), the value of GT would then be in the range of 11,250 to 72,000. According to Sincero (2003), GT value for effective flocculation is within the range of 50,000 to 250,000. Further study and analysis concluded that the design is effective for flocculation. Values for GT recorded during the study period are within the effective value and satisfied both MWA (1994) and Sincero (2003) design guideline. Minimum GT recorded is 58,295 and maximum GT is 61,686.

Through observation, the design of flocculation tank is flexible, which means it has the capability to vary hydraulic velocity gradient. Beside that, the flocculation tank consists of 10 compartments to minimise short circuiting. Design parameters could be improved by improving the distribution channel at the inlet zone of the flocculation tank. It can be seen at the site that the water does not distribute evenly for both flocculation tanks.

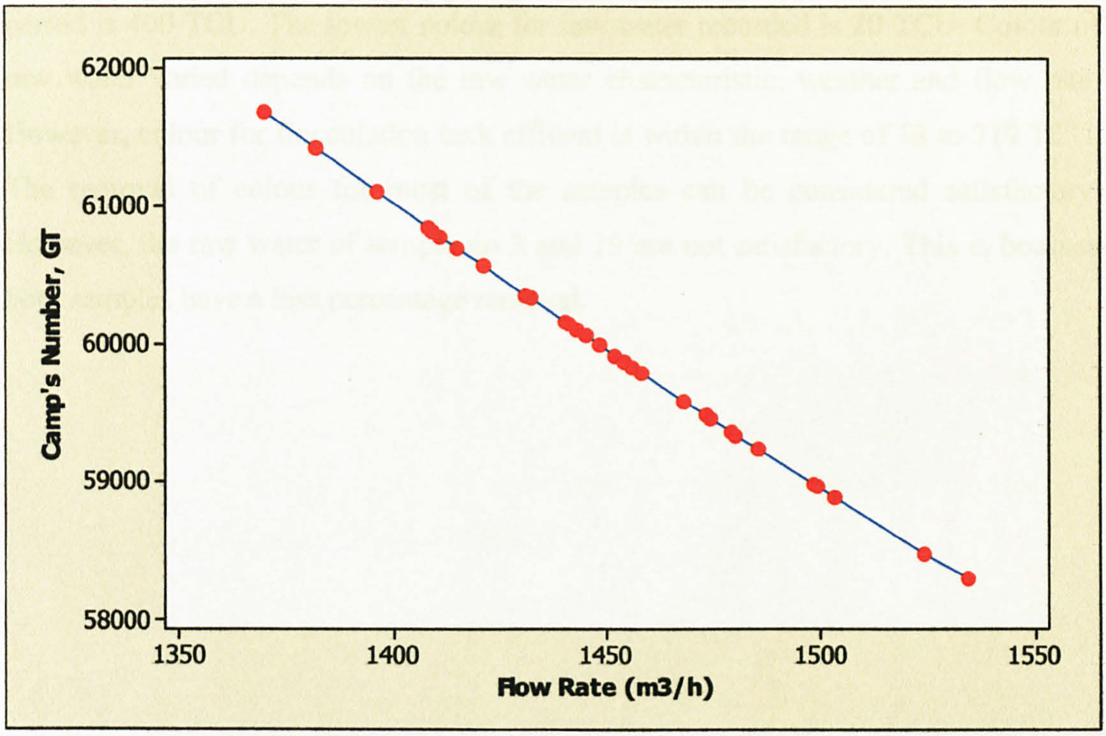

Figure 4.4 Camp Number, GT vs. Flow Rate

4.2 Percentage Removal of Colour, Turbidity and Total Suspended Solid for Hydraulic Coagulation and Flocculation

Condition of the water is determined qualitatively by its colour and odour. Colour is the first parameter that can be spotted through observation. Water should be colourless as possible. Presence of colour indicates the presence of complex organic compounds and colloidal forms of iron and manganese. It is necessary to differentiate between true colour due to the material in solution and apparent colour due to suspended matters (Tebbutt, 1998). Standard for colour in drinking water is less than 15 TCU and in raw water should be less than 300 TCU (MWA, 1994). According to MWA (1994), colour in the water could be reduced to the recommended limit by conventional treatment if the raw water does not contain more than 75 TCU.

Figure 4.5 shows removal of colour for all samples taken during the study period. It can be seen that the highest colour for raw water recorded during the study period is 400 TCU. The lowest colour for raw water recorded is 20 TCU. Colour of raw water varied depends on the raw water characteristic, weather and flow rate. However, colour for flocculation tank effluent is within the range of 13 to 319 TCU. The removal of colour for most of the samples can be considered satisfactory. However, the raw water of sample no 3 and 19 are not satisfactory. This is because both samples have a less percentage removal.

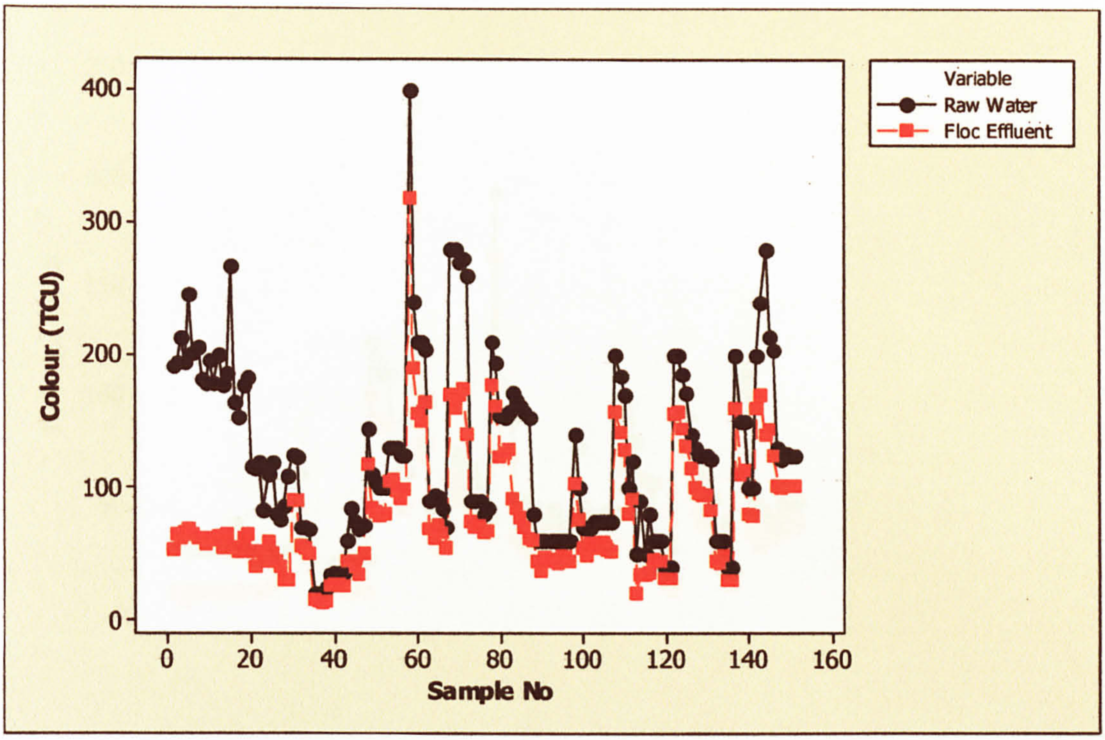

Figure 4.5 Removal of Colour

One of the problems with the measurement of turbidity especially low value in water sample is high degree of variability observed. Thus, it depends on the light source and the method of measurement (reflected versus transmitted light). Another problem often encountered is the light-absorbing properties of suspended materials. Turbidity readings at given facility such as water treatment plant can be used for control process. Besides that, turbidity has been used to monitor the performance of the hydraulic coagulation and flocculation. The presence of colloidal solids gives liquid a cloudy appearance which is aesthetically unattractive and may be harmful (Tebbutt, 1998). According to Tebbutt (1998), turbidity in the water is due to the presence of clay and silt particles, discharge of sewage or industrial wastes and presence of large number of microorganisms.

Figure 4.6 shows removal of turbidity for all samples taken at the water treatment plant. The lowest turbidity for raw water recorded during study the period is 10.3 NTU and the highest turbidity is 235 NTU. Turbidity of the raw water has large variation depends on weather. The removal of turbidity as indicated by the plotted graph can be considered satisfactory except for samples 6, 10, 16, 18 and 19.

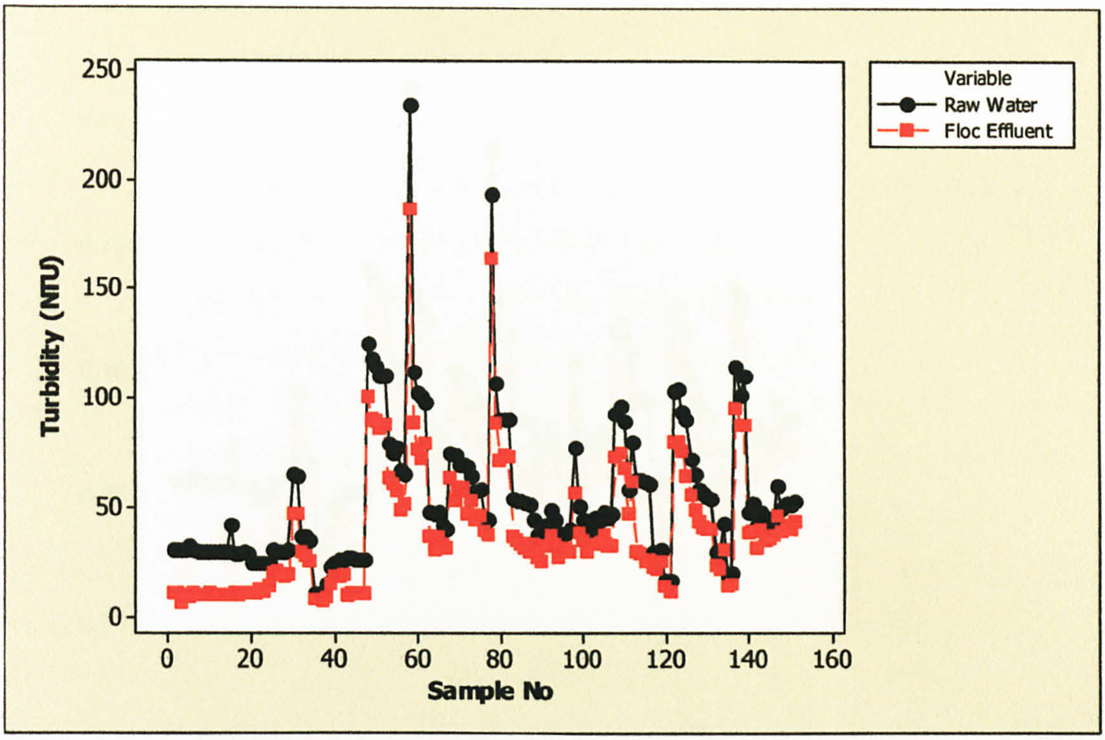

Figure 4.6 Removal of Turbidity

The suspended solids content the amount of particulate materials in a water sample. This includes both the organic and inorganic matters such as plankton, clay and silt. Suspended solids are discrete particles which can be measured by filtering a sample through a fine paper (Tebbutt, 1998). The suspended solids content of surface water can vary widely depending upon flow and season. Figure 4.7 shows the removal of total suspended solid for all samples taken during study period.

The lowest total suspended solid for raw water recorded during the study period is 0.028 mg/L and the highest total suspended solid is 0.213 mg/L. Total suspended solid of the raw water has large variation depends on water characteristic such as turbidity. The removal of total suspended solid as indicated by the plotted graph can be considered satisfactory except for samples 6, 10, 11, 13 and 17.

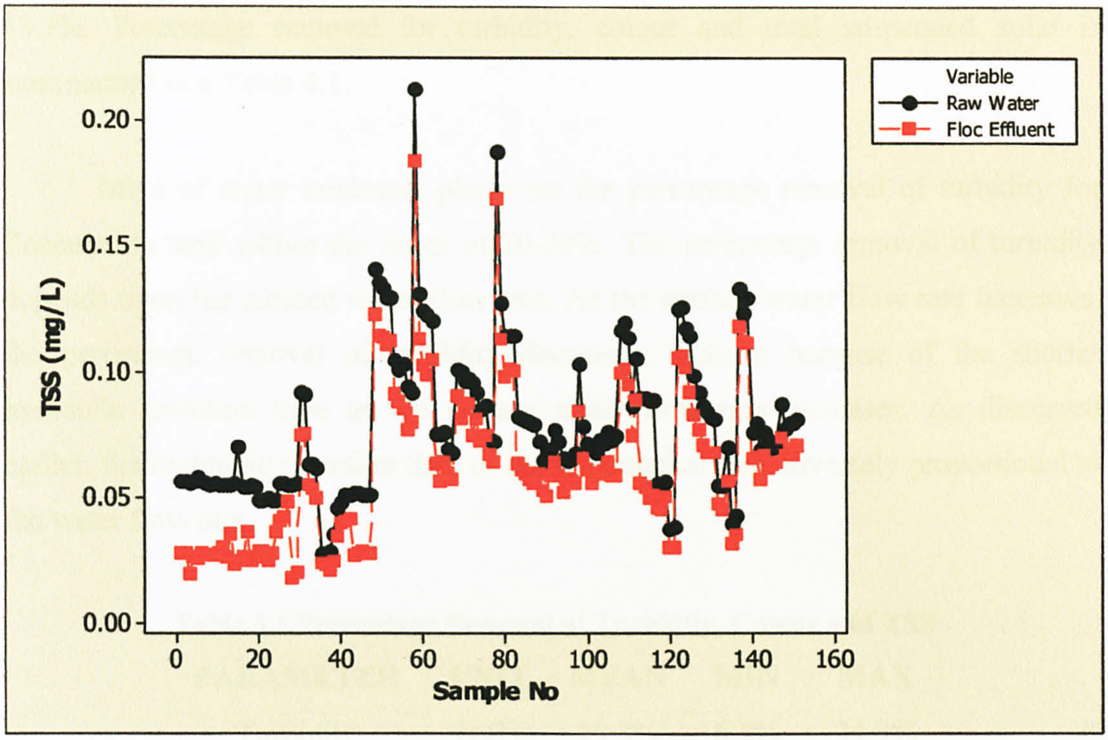

Figure 4.7 Removal of TSS

Low percentage removal of turbidity, colour and total suspended solid occurred due to improper dosage of alum. A reason for this event to happen is due to the short-circuiting in flow regime and lack of alertness of operators. The occurrence of short-circuit is due to sudden change in raw water quality. Since the quality of raw water may fluctuate due to the natural perturbation, the performance of water treatment plant relies on the operator's decision. Basically, dosage of alum is chosen empirically by the operators based on their past experiences and laboratory jar test. The water treatment process operation is known vary from time to time. Percentage removal decreases when inexperienced operators are on duty and when weather is rapidly changes. It is important for operators to rapidly monitor the quality of raw water and react when necessary.

Percentage removal of colour is within the range of 6.2% to 66.7%. Average percentage removal of colour is 23.1%. The percentage removal of colour depends on the surface water flow rate. Meanwhile, percentage removal of turbidity for flocculation tank is within the range of 6.3% to 34.3%. Average percentage removal for turbidity is 19.8%. Percentage removal of total suspended solid is within the range of 2.7% to 23.9%. The average percentage removal for total suspended solid is

13.7%. Percentage removal for turbidity, colour and total suspended solid is summarised in a Table 4.1.

Most of water treatment plants set the percentage removal of turbidity for flocculation tank within the range of 20-30%. The percentage removal of turbidity depends upon the surface water flow rate. As the surface water flow rate increases, the percentage removal of turbidity decreases. This is because of the shorter hydraulic retention time as the surface water flow rate increases. As discussed earlier, the hydraulic retention time of the flocculation tank inversely proportional to the water flow rate.

Table 4.1 Percentage Removal of Turbidity, Colour and TSS

PARAMETER	UNIT	MEAN	MIN	MAX
Turbidity	NTU	19.8%	6.3%	34.3%
Colour	TCU	23.1%	6.2%	66.7%
TSS	mg/L	13.7%	2.7%	23.9%

4.3 Effects of Flow Rate and Temperature on the Performance of Hydraulic Coagulation and Flocculation

As mentioned earlier, the performance of hydraulic coagulation and flocculation depends on the flow rate. Theoretically, the performance of the hydraulic coagulation and flocculation decreases as the flow rate increases. This is due to short hydraulic retention time in the flocculation tank. This theory is based on the constant water characteristics and control dosage of alum.

Referring to Figure 4.8, there is no significant variation of flow rate. It can be seen that the boxplot of flow rate has a small variation except for samples on the 6th and 16th March 2009. The large variation is caused by the pump shut down due to high level of storage reservoir. Since there is small variation of flow rate, there is no significant effect of flow rate on the performance of hydraulic coagulation and flocculation of Sg. Kampar Water Treatment Plant.

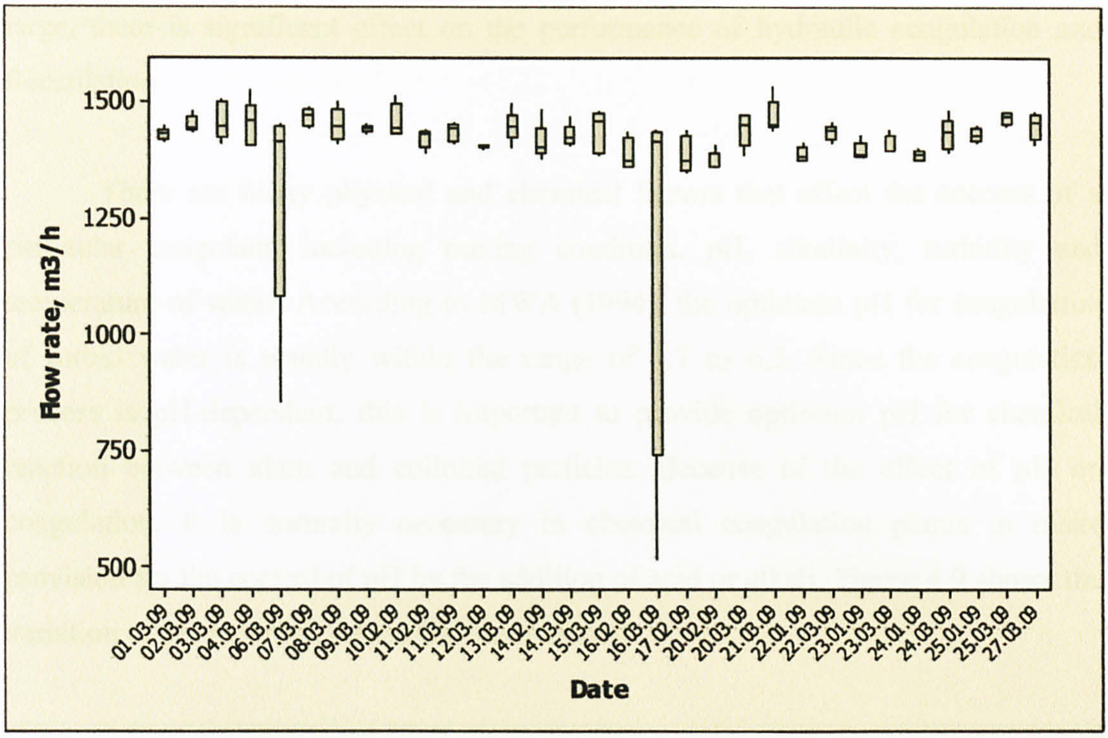

Figure 4.8 Boxplot of Flow Rate

Temperature is very important for speeding up the chemical reactions, reduction in solubility of gases, amplification of tastes and odours (Tebbutt, 1998). Physical properties of water such as density, solubility, vapour pressure and electrical conductivity is depends on the temperature. Beside that, temperature also plays an important role in determining the rate of chemical reactions. Temperature of all samples recorded during the study period is 27 °C. Thus, there is no significance effect on the performance of hydraulic coagulation and flocculation since the temperature for all sample during study period are constant.

4.4 Effects of pH and Dosage of Alum on the Performance of Hydraulic Coagulation and Flocculation

The pH of most of the samples is in the range of 5.41 to 7.28. The pH of most natural waters is in the range of 4.0 to 9.0 (MWA, 1994). The recommended pH value for treated water is within the range of 6.5 to 9.0 (MWA, 1994). The pH value is very important as a parameter in water chemistry since many of the water treatment processes are pH-dependent. Since the variation of pH of the samples is large, there is significant effect on the performance of hydraulic coagulation and flocculation.

There are many physical and chemical factors that affect the success of a particular coagulant, including mixing condition, pH, alkalinity, turbidity and temperature of water. According to MWA (1994), the optimum pH for coagulation of turbid water is usually within the range of 5.7 to 6.5. Since the coagulation process is pH-dependant, this is important to provide optimum pH for chemical reaction between alum and colloidal particles. Because of the effect of pH on coagulation, it is normally necessary in chemical coagulation plants to make provision for the control of pH by the addition of acid or alkali. Figure 4.9 shows the variation of pH recorded during the study period

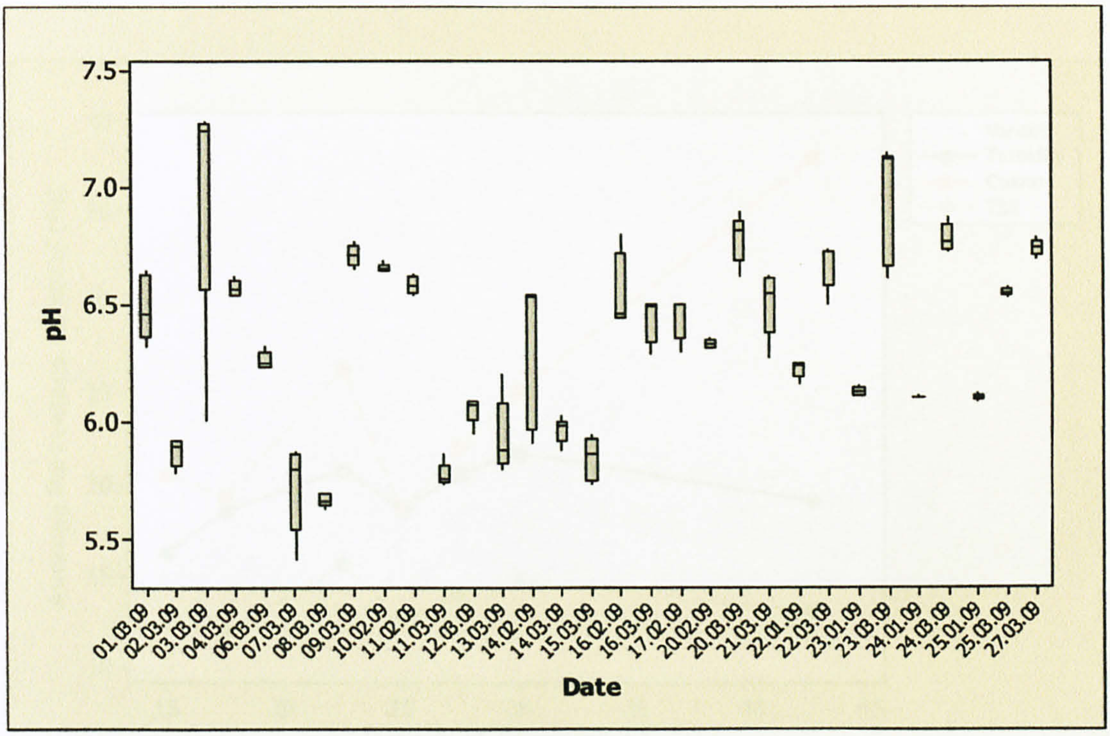

Figure 4.9 Boxplot of pH

Alum usually affected by the alkalinity of the raw water. Increases in turbidity, temperature and mixing energy can also improve coagulation. Percentage removal of turbidity, colour and total suspended solid depends on the raw water quality. As discussed earlier, the percentage removal is based on the dosage of alum and flow rate. Referring to Figure 4.10, the average percentage removal is varied between different dosages of alum. Highest average percentage removal of colour, turbidity and total suspended solid is 38%, 21.8% and 15.6% respectively. From the graph, the percentage removal of turbidity, colour and total suspended solid is inconsistent with the increases of dosage of alum.

The coagulant and dosage selected for particular water is based on the jar test. Jar test evaluates the actual performance of coagulant at different concentration in water. For aluminium sulphate ($Al_2(SO_4)_3$), the typical dose is between 10 to 50 mg/L (MWA, 1994). The dosage of alum for Sg. Kampar Water Treatment Plant is considered satisfactory as the dosage is within the range recommended by MWA (1994) guideline. However, the percentage removal for alum dose more than 25 mg/L is considered low. The major factor is due to the rapid change of raw water characteristic and weather.

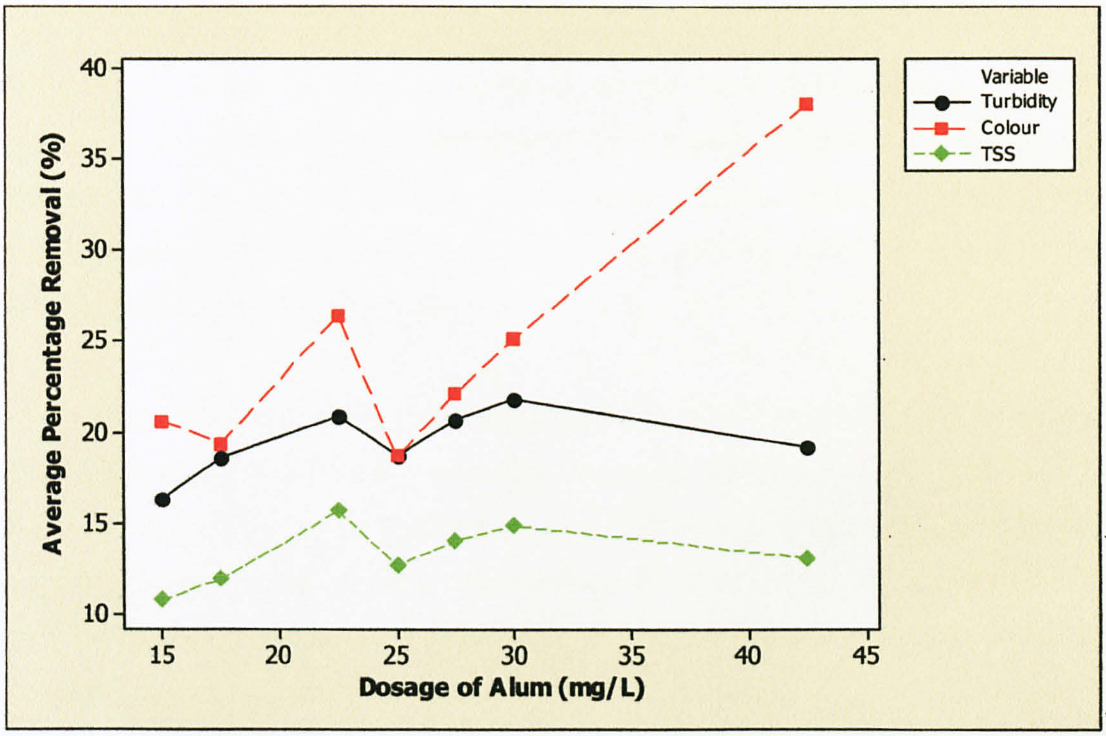

Figure 4.10 Average Percentage Removal vs. Dosage of Alum

The performance of flocculation regarding to the alum dosage is shown in Table 4.2. Table 4.2 shows the average percentage removal of turbidity, colour and total suspended solid due to the different dosage of alum.

Table 4.2 Percentage Removal of Turbidity, Colour and TSS due to Alum Dosage

Dosage mg/L	Turbidity (%)			Colour (%)			TSS (%)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
15	16.3	8.0	34.3	20.6	6.2	23.9	10.7	5.3	23.9
17.5	18.6	6.3	29.0	19.4	7.1	42.0	11.9	2.7	17.3
22.5	20.9	11.3	30.6	26.4	14.3	66.7	15.6	7.7	21.1
25	18.6	11.6	33.2	18.6	11.6	23.1	12.6	7.7	23.1
27.5	20.6	12.2	32.6	22.2	15.9	36.4	14.0	8.1	22.6
30	21.8	14.9	30.6	25.1	14.9	50.8	14.8	9.9	21.2
42.5	19.2	11.4	27.6	38.0	35.2	41.7	13.1	7.6	19.0

CHAPTER 5
CONCLUSION AND RECOMMENDATION

A study on the performance of hydraulic coagulation and flocculation for Sg. Kampar Water Treatment Plant is investigated in this paper and conclusions can be drawn as follows.

5.1 Design Parameters for Mixing Basin and Flocculation Tank

Average flow rate during study period is 1418 m^3/h. For mixing basin, hydraulic head loss recorded is 0.76 m. Average power dissipation for mixing is 2935 N.m/s. Power dissipation increases as the flow rate increases. Average hydraulic velocity gradient recorded is 1056 sec^{-1}. It can be seen from the results that the hydraulic velocity gradient slightly increases with the increases of flow rate. Mean hydraulic retention time for mixing basin is 14.86 sec. It can be concluded that the design of mixing basin is appropriate.

For flocculation tank, the average power dissipation recorded is 556 N.m/s. The power dissipation does not have large variation. Average hydraulic head loss is 0.144 m. Hydraulic velocity gradient for flocculation tank is 26 sec^{-1}. The hydraulic velocity gradient is also slightly constant with small variation. Hydraulic retention time for flocculation tank is 39 minutes. It also can be concluded that the design of flocculation tank is also appropriate.

Since both design for mixing basin and flocculation tank is appropriate, it can be concluded that mixing basin and flocculation tank provides effective mixing and effective flocculation respectively. All design parameter for mixing basin and flocculation tank are in accordance with the MWA (1994) guideline.

5.2 Performance of Hydraulic Coagulation and Flocculation

Turbidity for raw water is within the range of 10.3 to 235 NTU. During rainy season, the turbidity of raw water increases. The surface water flow is extremely turbulent and highly comprised of clay particles and organic matters. The percentage removal for turbidity is within the range of 6.3% to 34.3%. The mean percentage removal for turbidity is 19.8%. It can be concluded that the percentage removal for turbidity is satisfactory.

The highest colour of raw water recorded is 400 TCU and the lowest is 20 TCU. The average percentage removal for colour is 23.1%. Maximum percentage removal for colour recorded is 66.7% and minimum is 6.2%. Similar to the percentage removal of turbidity, it can be concluded that the percentage removal of colour is also satisfactory.

The lowest TSS for raw water recorded during study period is 0.028 mg/L and the highest turbidity is 0.213 mg/L. The surface water flow is extremely turbulent and highly comprised of organic and inorganic matters such as plankton, clay and silt. The suspended solids content of surface water can vary widely depending upon flow and season. The percentage removal for total suspended solid is within the range of 2.7% to 23.9%. The mean of percentage removal for total suspended solid is 13.7%. It can be concluded that the percentage removal for total suspended solid is satisfactory.

5.3 Effect of Flow Rate, Temperature, pH and Dosage of Alum on the Performance of Hydraulic Coagulation and Flocculation

The performance of the hydraulic coagulation and flocculation tank depends on many variables such as dosage of coagulant, water quality, alkalinity and temperature. In the study, it can be concluded that there is no effect of flow rate on the performance of hydraulic coagulation and flocculation of Sg. Kampar Water Treatment Plant. This is due consistent flow rate during study period. In addition, temperature of raw water also has not affected the performance of the hydraulic coagulation and flocculation. This is due consistent temperature during study period.

The pH of the water has effected on the performance of the hydraulic coagulation and flocculation. This is because the coagulation process is pH-dependant and it is required to obtain optimum pH for coagulation. The pH of coagulation is critical if the best quality is to be achieved (Stevenson, 1997).

Dosage of alum also has impact on the performance of hydraulic coagulation and flocculation. Optimum dosage of alum is based on jar test. Jar test is done to evaluate the actual performance of alum at different concentration of water. It is important to obtain optimum dosage of alum that result in high percentage removal of turbidity, colour and total suspended solid.

5.4 Recommendations

These recommendations should be taken to ensure better result and outcomes of this study in the future. The recommendations for the study are:

1. The setting-up of apparatus for all laboratory tests should comply with the standard and ensure the apparatus should be clean to reduce experimental error.
2. Samples should be taken at the same points to reduce large variation of the result.
3. More samples should be taken for a thorough understanding of performance of the hydraulic coagulation and flocculation of the water treatment plant.
4. Laboratory tests should be conducted immediately after the samples taken from the water treatment plant.

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APPENDICES

APPENDIX A	EXPERIMENTAL DATA AND RESULT
APPENDIX B	MIXING BASIN AND FLOCCULATION TANK DESIGN CALCULATION
APPENDIX C	MIXING BASIN AND FLOCCULATION TANK TECHNICAL DRAWING
APPENDIX D	GANTT CHART
APPENDIX E	MIXING BASIN AND FLOCCULATION TANK PHOTO

APPENDIX A

EXPERIMENTAL DATA AND RESULT

Table A 1.1 Data for the Study on hydraulic coagulation and Flocculation Process of Sg Kampar Water Treatment Plant

No	Date	Time	Flow rate, m3/h	Raw water					Alum dose,	Inlet			Outlet			Turbidity %	Colour %	TSS %
				Temp, C	pH	Turbidity	Colour	TSS		Turbidity	Colour	TSS	Turbidity	Colour	TSS			
1	22.01.09	12.00 PM	1382	27	6.25	30.44	192	0.056	15	11.9	75	0.031	10.3	53	0.028	13.4	29.3	9.0
		1.00 PM	1394	27	6.25	30.27	195	0.056	15	12.6	81	0.032	10.5	65	0.028	16.7	19.8	11.2
		2.00 PM	1411	27	6.24	30.15	213	0.056	15	9.19	65	0.026	6.04	61	0.020	34.3	6.2	23.9
		3.00 PM	1376	27	6.22	30.28	194	0.056	15	12.5	80	0.032	9.55	66	0.027	23.6	17.5	16.1
		4.00 PM	1376	27	6.16	32.11	246	0.058	15	10.3	79	0.028	8.89	68	0.025	13.7	13.9	9.1
2	23.01.09	8.30 AM	1385	27	6.15	30.74	202	0.057	15	11.28	74	0.030	10.3	65	0.028	8.7	12.2	5.7
		9.30 AM	1428	27	6.13	29.81	205	0.056	15	11.9	82	0.031	10	62	0.027	16.0	24.4	10.7
		10.30 AM	1397	27	6.13	29.25	182	0.055	15	11.9	74	0.031	10	61	0.027	16.0	17.6	10.7
		11.30 PM	1386	27	6.12	29.7	179	0.055	15	11.6	70	0.030	10	57	0.027	13.8	18.6	9.2
		12.30 PM	1384	27	6.11	29.6	196	0.055	15	11.2	74	0.029	10.3	60	0.028	8.0	18.9	5.3
3	24.01.09	1.00 PM	1377	27	6.11	29.43	179	0.055	15	12.2	74	0.032	9.86	62	0.03	19.2	16.2	6.3
		2.00 PM	1400	27	6.1	29.35	200	0.055	15	11.3	77	0.03	10.1	63	0.026	10.6	18.2	13.3
		3.00 PM	1389	27	6.1	29.51	178	0.055	15	11.3	68	0.037	9.93	54	0.035	12.1	20.6	5.4
		4.00 PM	1376	27	6.1	29.94	186	0.056	15	11.4	71	0.026	9.38	64	0.023	17.7	9.9	11.5
		5.00 PM	1388	27	6.1	42.23	267	0.070	15	11.3	66	0.027	9.92	54	0.025	12.2	18.2	7.4
4	25.01.09	11.00 AM	1411	27	6.1	28.62	165	0.054	17.5	11.1	64	0.028	10.4	54	0.026	6.3	15.6	7.1
		12.00 PM	1424	27	6.1	28.89	153	0.054	17.5	11.5	61	0.037	9.8	52	0.036	14.8	14.8	2.7
		1.00 PM	1447	27	6.12	29.25	178	0.055	17.5	11.2	68	0.028	10.3	61	0.025	8.0	10.3	10.7
		2.00 PM	1430	27	6.09	28.67	182	0.054	17.5	11	70	0.03	10.2	65	0.026	7.3	7.1	13.3
5	10.02.09	11.00 AM	1431	27	6.64	24.62	116	0.049	17.5	13.6	64	0.033	10.7	52	0.029	21.3	18.8	14.5
		12.00 PM	1435	27	6.64	24.58	114	0.049	17.5	14.9	69	0.035	10.7	40	0.029	28.2	42.0	19.4
		1.00 PM	1483	27	6.65	24.85	119	0.049	17.5	15	72	0.03	12.7	51	0.025	15.3	29.2	16.7
		2.00 PM	1515	27	6.66	24.8	83	0.049	17.5	15.5	52	0.032	11	44	0.028	29.0	15.4	12.5
		3.00 PM	1446	27	6.68	24.54	110	0.049	17.5	16.1	72	0.039	13.7	58	0.036	14.9	19.4	7.7

Table A 1.2 Data for the Study on hydraulic coagulation and Flocculation Process of Sg Kampar Water Treatment Plant

No	Date	Time	Flow rate, m3/h	Raw water					Alum	Inlet			Outlet			Turbidity	Colour %	TSS %
				Temp, C	pH	Turbidity	Colour	TSS	dose,	Turbidity	Colour	TSS	Turbidity	Colour	TSS	%		
6	11.02.09	3.00 PM	1432	27	6.54	30.17	118	0.056	22.5	24.2	95	0.051	20.2	50	0.041	16.5	47.4	19.6
		4.00 PM	1417	27	6.56	29.82	81	0.056	22.5	24	65	0.048	20.7	45	0.042	13.8	30.8	12.5
		5.00 PM	1436	27	6.58	29.53	75	0.055	22.5	23.5	60	0.052	19.6	40	0.048	16.6	33.3	7.7
		6.00 PM	1439	27	6.61	29.49	86	0.055	22.5	24	70	0.022	18.3	30	0.018	23.8	57.1	18.2
		7.00 PM	1391	27	6.63	30.23	109	0.056	22.5	24.9	90	0.025	19.6	30	0.02	21.3	66.7	20.0
7	14.02.09	11.00 AM	1485	27	5.91	64.9	125	0.092	25	60.2	116	0.088	47.2	91	0.075	21.7	21.7	14.7
		12.00 PM	1402	27	6.03	64.1	123	0.092	25	60.3	116	0.088	47.2	91	0.075	21.7	21.7	14.7
		1.00 PM	1381	27	6.53	36.5	70	0.063	25	34.2	66	0.061	29.4	56	0.055	14.2	14.2	9.5
		2.00 PM	1405	27	6.53	36.3	70	0.063	25	34.1	66	0.061	28.3	55	0.054	17.1	17.1	11.5
		3.00 PM	1403	27	6.54	34.9	69	0.062	25	30	59	0.056	25.1	50	0.050	16.3	16.3	11.0
8	16.02.09	3.00 PM	1435	27	6.46	10.5	20	0.028	17.5	9.7	18	0.027	8.2	16	0.024	15.5	15.5	10.4
		4.00 PM	1367	27	6.44	10.3	20	0.028	17.5	9.4	18	0.026	7.9	14	0.023	16.0	21.7	10.7
		5.00 PM	1362	27	6.46	10.7	20	0.029	17.5	9.1	17	0.026	6.8	13	0.021	25.3	22.0	17.3
		6.00 PM	1385	27	6.8	15.1	25	0.036	17.5	11.1	18	0.029	8.5	15	0.025	23.4	20.0	15.9
9	17.02.09	11.00 AM	1440	27	6.5	22.51	35	0.046	17.5	18.6	29	0.041	14.5	25	0.035	22.0	13.1	15.0
		12.00 PM	1351	27	6.5	24.2	36	0.049	17.5	23.8	35	0.048	18.0	27	0.040	24.2	24.2	16.5
		1.00 PM	1362	27	6.3	26.32	36	0.051	17.5	24.5	34	0.049	18.6	27	0.041	24.1	20.0	16.4
		2.00 PM	1387	27	6.5	26.16	36	0.051	17.5	24	33	0.048	19.2	26	0.042	20.0	20.0	13.5
10	20.02.09	8.30 AM	1409	27	6.35	26.88	60	0.052	15	11.7	50	0.030	9.7	44	0.027	17.1	12.0	11.5
		9.30 AM	1364	27	6.34	27.12	85	0.052	15	13.1	70	0.033	10.2	45	0.028	22.1	35.7	15.0
		10.30 AM	1362	27	6.33	26.56	74	0.052	15	12.5	65	0.032	10.7	40	0.029	14.4	38.5	9.6
		11.30 PM	1365	27	6.32	26.34	68	0.051	15	12.3	60	0.031	10.2	35	0.028	17.1	41.7	11.5
		12.30 PM	1371	27	6.31	26.37	72	0.051	15	12.5	65	0.032	10.2	50	0.028	18.4	23.1	12.4

Table A 1.3 Data for the Study on hydraulic coagulation and Flocculation Process of Sg Kampar Water Treatment Plant

No	Date	Time	Flow rate, m3/h	Raw water					Alum	Inlet			Outlet			Turbidity	Colour %	TSS %
				Temp, C	pH	Turbidity	Colour	TSS	dose,	Turbidity	Colour	TSS	Turbidity	Colour	TSS	%		
11	01.03.09	11.00 AM	1448	27	6.32	125	145	0.141	27.5	123.3	143	0.140	100.6	117	0.123	18.4	18.4	12.4
		12.00 PM	1422	27	6.46	118	110	0.136	27.5	115.6	108	0.134	90.5	84	0.115	21.7	21.7	14.7
		1.00 PM	1435	27	6.4	115	105	0.134	27.5	114.2	104	0.133	89.4	82	0.114	21.8	21.8	14.8
		2.00 PM	1416	27	6.62	110	100	0.130	27.5	109.2	99	0.129	86.4	79	0.111	20.9	20.9	14.2
		3.00 PM	1431	27	6.64	110	100	0.130	27.5	109	99	0.129	87.8	80	0.112	19.4	19.4	13.1
12	02.03.09	3.00 PM	1445	27	5.78	79.4	130	0.105	27.5	76.9	126	0.103	63.5	104	0.091	17.4	17.4	11.7
		4.00 PM	1436	27	5.84	74.9	130	0.101	27.5	72.4	126	0.099	60.9	106	0.089	15.9	15.9	10.6
		5.00 PM	1460	27	5.89	77.3	130	0.103	27.5	75.7	127	0.102	57.6	97	0.085	24.0	24.0	16.3
		6.00 PM	1446	27	5.91	66.7	125	0.094	27.5	64.8	121	0.092	48.8	92	0.077	24.6	24.6	16.8
		7.00 PM	1480	27	5.92	64.9	125	0.092	27.5	63.8	123	0.091	51.7	98	0.080	19.0	20.0	12.8
13	03.03.09	8.30 AM	1498	27	6.01	235	400	0.213	30	230.3	392	0.210	187.2	319	0.184	18.7	18.7	12.6
		9.30 AM	1439	27	7.12	112	240	0.132	30	110	236	0.130	88.7	190	0.113	19.4	19.4	13.1
		10.30 AM	1448	27	7.28	103	210	0.125	30	99.2	202	0.122	76.4	156	0.103	23.0	23.0	15.7
		11.30 PM	1412	27	7.24	101	210	0.123	30	99.2	206	0.122	72.4	150	0.099	27.1	27.1	18.6
		12.30 PM	1504	27	7.26	98	205	0.121	30	97.4	204	0.120	78.9	165	0.105	19.0	19.0	12.8
14	04.03.09	3.00 PM	1524	27	6.54	47.7	90	0.076	25	45.7	86	0.073	36.6	69	0.064	20.0	20.0	13.5
		4.00 PM	1461	27	6.54	47.3	95	0.075	25	45.5	91	0.073	30.4	61	0.056	33.2	33.2	23.1
		5.00 PM	1409	27	6.56	48	93	0.076	25	46.1	89	0.074	36.9	71	0.064	20.0	20.0	13.5
		6.00 PM	1408	27	6.62	42.1	85	0.070	25	40.2	81	0.068	32.9	66	0.059	18.2	18.2	12.2
		7.00 PM	1459	27	6.58	40.2	70	0.068	25	39.1	68	0.066	31.5	55	0.058	19.4	19.4	13.1
15	06.03.09	8.30 AM	1454	27	6.25	75	280	0.101	42.5	73.5	270	0.100	63.1	170	0.091	14.1	37.0	9.5
		9.30 AM	1447	27	6.24	73.8	280	0.100	42.5	73.2	268	0.100	53.2	160	0.081	27.3	40.3	18.8
		10.30 AM	1416	27	6.23	69.5	270	0.096	42.5	68.2	265	0.095	57.5	170	0.085	15.7	35.8	10.5
		11.30 AM	1307	27	6.28	70	273	0.097	42.5	67.3	270	0.094	59.6	175	0.087	11.4	35.2	7.6
		12.30 PM	854	27	6.32	69.1	260	0.096	42.5	64.8	240	0.092	46.9	140	0.075	27.6	41.7	19.0

Table A 1.4 Data for the Study on hydraulic coagulation and Flocculation Process of Sg Kampar Water Treatment Plant

No	Date	Time	Flow rate, m3/h	Raw water					Alum dose,	Inlet			Outlet			Turbidity %	Colour %	TSS %
				Temp, C	pH	Turbidity	Colour	TSS		Turbidity	Colour	TSS	Turbidity	Colour	TSS			
16	07.03.09	10.00 AM	1480	27	5.8	64.6	90	0.092	25	63.2	88	0.091	53.5	75	0.081	15.3	15.3	10.3
		11.00 AM	1488	27	5.86	57.3	90	0.085	25	56.7	89	0.085	44.6	70	0.072	21.3	21.3	14.4
		12.00 PM	1450	27	5.67	58.7	90	0.086	25	55.6	85	0.083	46.5	71	0.074	16.4	16.4	11.0
		1.00 PM	1443	27	5.87	45.3	80	0.073	25	44.8	75	0.072	39.6	66	0.067	11.6	11.6	7.7
		2.00 PM	1473	27	5.41	44.7	85	0.072	25	42.9	77	0.070	37.2	67	0.064	13.3	13.3	8.9
17	08.03.09	10.00 AM	1503	27	5.66	194	210	0.188	30	193.1	209	0.188	164.2	178	0.169	15.0	15.0	10.0
		11.00 AM	1410	27	5.66	107	194	0.128	30	106	192	0.127	89.0	161	0.113	16.0	16.0	10.7
		12.00 PM	1432	27	5.69	90.4	155	0.114	30	87.4	150	0.112	71.4	122	0.098	18.3	18.3	12.3
		1.00 PM	1449	27	5.69	90.7	153	0.115	30	87.2	147	0.112	74.2	125	0.101	14.9	14.9	9.9
		2.00 PM	1470	27	5.63	90.2	158	0.114	30	87.2	153	0.112	73.5	129	0.100	15.7	15.7	10.5
18	09.03.09	3.00 PM	1452	27	6.652	54.374	171	0.082	30	48.32	150	0.076	36.2	92	0.063	25.0	38.7	17.1
		4.00 PM	1447	27	6.679	53.525	167	0.081	30	46.98	144	0.075	34.6	84.5	0.061	26.3	41.3	18.0
		5.00 PM	1443	27	6.706	52.676	162	0.081	30	45.64	138	0.073	33.0	77	0.059	27.7	44.2	19.0
		6.00 PM	1438	27	6.733	51.827	158	0.080	30	44.3	132	0.072	31.4	69.5	0.058	29.1	47.3	20.0
		7.00 PM	1434	27	6.76	50.978	153	0.079	30	42.96	126	0.071	29.8	62	0.056	30.6	50.8	21.2
19	11.03.09	2.00 PM	1456	27	5.75	44.5	80	0.072	27.5	43.2	78	0.071	33.1	60	0.060	23.4	23.4	15.9
		3.00 PM	1413	27	5.86	37.4	60	0.064	27.5	36.5	59	0.063	27.5	44	0.053	24.7	24.7	16.9
		4.00 PM	1422	27	5.76	40.7	60	0.068	27.5	37.8	56	0.065	25.5	38	0.050	32.6	32.6	22.6
		5.00 PM	1450	27	5.73	41.7	60	0.069	27.5	39.1	56	0.066	32.5	47	0.059	16.9	16.9	11.3
		6.00 PM	1443	27	5.76	49.1	60	0.077	27.5	47.6	58	0.075	37.1	45	0.064	22.0	22.0	14.9
20	12.03.09	2.00 PM	1405	27	5.95	44.5	60	0.072	30	43.2	58	0.071	32.7	44	0.059	24.3	24.3	16.6
		3.00 PM	1401	27	6.06	38.2	60	0.065	30	37.2	58	0.064	27.0	42	0.052	27.4	27.4	18.8
		4.00 PM	1408	27	6.08	37.8	60	0.065	30	37.2	59	0.064	31.0	49	0.057	16.6	16.6	11.2
		5.00 PM	1404	27	6.09	38.4	60	0.066	30	37.8	59	0.065	30.5	48	0.056	19.4	19.4	13.1
		6.00 PM	1406	27	6.07	40.2	60	0.068	30	39.3	59	0.067	29.7	44	0.055	24.5	24.5	16.8

Table A 1.5 Data for the Study on hydraulic coagulation and Flocculation Process of Sg Kampar Water Treatment Plant

No	Date	Time	Flow rate, m3/h	Raw water					Alum	Inlet			Outlet			Turbidity	Colour %	TSS %
				Temp, C	pH	Turbidity	Colour	TSS	dose,	Turbidity	Colour	TSS	Turbidity	Colour	TSS	%		
21	13.03.09	3.00 PM	1499	27	5.8	77.2	140	0.103	22.5	75.4	137	0.102	56.8	103	0.085	24.7	24.7	16.8
		4.00 PM	1449	27	5.84	50.7	100	0.079	22.5	47.8	94	0.076	38.3	76	0.065	19.9	19.9	13.5
		5.00 PM	1403	27	5.88	44.2	70	0.072	22.5	43.2	68	0.071	34.7	55	0.061	19.7	19.7	13.3
		6.00 PM	1443	27	5.96	42.8	70	0.070	22.5	40.8	67	0.068	29.8	49	0.056	26.9	26.9	18.5
		7.00 PM	1447	27	6.2	40.2	70	0.068	22.5	38.9	68	0.066	33.3	58	0.060	14.3	14.3	9.5
22	14.03.09	9.00 AM	1468	27	5.88	45.7	75	0.073	22.5	43.7	72	0.071	33.1	54	0.060	24.3	24.3	16.6
		10.00 AM	1426	27	5.96	44.1	75	0.072	22.5	43.2	73	0.071	33.8	57	0.060	21.8	21.8	14.8
		11.00 AM	1412	27	5.98	48.1	75	0.076	22.5	46.5	73	0.074	37.3	58	0.064	19.8	19.8	13.4
		12.00 PM	1408	27	5.98	45.5	75	0.073	22.5	44.3	73	0.072	32.6	54	0.059	26.5	26.5	18.2
		1.00 PM	1430	27	6.02	47.1	75	0.075	22.5	46.7	74	0.074	32.4	52	0.059	30.6	30.6	21.1
23	15.03.09	2.30 PM	1473	27	5.92	93.4	200	0.117	30	92.5	198	0.116	73.2	157	0.100	20.9	20.9	14.2
		3.30 PM	1386	27	5.94	96.7	184	0.120	30	95.7	182	0.119	74.6	142	0.101	22.0	22.0	14.9
		4.30 PM	1393	27	5.73	89.3	170	0.114	30	88.2	168	0.113	67.8	129	0.095	23.1	23.1	15.7
		5.30 PM	1461	27	5.86	58.7	100	0.086	30	57.2	97	0.085	46.6	79	0.074	18.5	18.5	12.5
		6.30 PM	1481	27	5.76	80.2	120	0.106	30	78.6	118	0.105	61.5	92	0.089	21.8	21.8	14.8
24	16.03.09	10.30 AM	1421	27	6.49	62.35	50	0.090	27.5	38.2	30	0.065	30	20	0.056	21.5	33.3	14.6
		11.30 AM	1409	27	6.49	62.28	90	0.090	27.5	37	50	0.064	28.6	35	0.054	22.7	30.0	15.4
		12.30 PM	1439	27	6.5	61.4	50	0.089	27.5	34.4	45	0.061	25	35	0.050	27.3	22.2	18.8
		1.30 PM	516	27	6.29	61.28	80	0.089	27.5	34.8	47	0.062	26.2	36	0.051	24.7	23.4	16.9
25	20.03.09	2:00 PM	1474	27	6.89	29.9	60	0.056	22.5	28.7	57	0.054	22.4	46	0.046	22.0	19.3	14.9
		3:00 PM	1474	27	6.74	28.3	60	0.054	22.5	27.9	56	0.053	21.5	44	0.045	22.9	21.4	15.6
		4:00 PM	1453	27	6.62	30.6	60	0.057	22.5	29.2	58	0.055	25.6	45	0.050	12.3	22.4	8.2
		5:00 PM	1387	27	6.82	16.2	40	0.037	22.5	16	38	0.037	14.2	31	0.030	11.3	18.4	19.8
		6:00 PM	1427	27	6.81	16.7	40	0.038	22.5	15.8	38	0.037	11.5	32	0.030	27.2	15.8	18.7

Table A 1.6 Data for the Study on hydraulic coagulation and Flocculation Process of Sg Kampar Water Treatment Plant

No	Date	Time	Flow rate, m3/h	Raw water					Alum dose,	Inlet			Outlet			Turbidity %	Colour %	TSS %
				Temp, C	pH	Turbidity	Colour	TSS		Turbidity	Colour	TSS	Turbidity	Colour	TSS			
26	21.03.09	3.00 PM	1534	27	6.6	103.3	200	0.125	27.5	99.2	198	0.122	80.2	156	0.106	19.2	21.2	12.9
		4.00 PM	1465	27	6.62	104.5	200	0.126	27.5	99.1	198	0.122	80.3	157	0.106	19.0	20.7	12.8
		5.00 PM	1442	27	6.55	94.3	186	0.118	27.5	90.2	184	0.114	75.6	145	0.102	16.2	21.2	10.9
		6.00 PM	1453	27	6.49	90.7	172	0.115	27.5	87.4	169	0.112	64.6	132	0.092	26.1	21.9	17.9
		7.00 PM	1451	27	6.27	72.5	140	0.099	27.5	68.3	138	0.095	55.3	115	0.083	19.0	16.7	12.8
27	22.03.09	2:00 PM	1458	27	6.5	64.9	130	0.092	25	60.3	127	0.088	48.7	100	0.077	19.2	21.3	13.0
		3:00 PM	1443	27	6.66	58.7	125	0.086	25	56.7	123	0.085	43.2	96	0.071	23.8	22.0	16.2
		4:00 PM	1426	27	6.72	56.8	125	0.085	25	52.7	123	0.081	40.8	95	0.068	22.6	22.8	15.3
		5:00 PM	1411	27	6.73	54.6	124	0.082	25	52.3	121	0.080	40.4	95	0.068	22.8	21.5	15.5
		6:00 PM	1441	27	6.72	53.8	122	0.082	25	50.2	118	0.078	40.4	83	0.068	19.5	29.7	13.2
28	23.03.09	2.30 PM	1396	27	7.12	29.4	60	0.055	22.5	27.9	58	0.053	23.2	45	0.047	16.8	22.4	11.3
		3.30 PM	1397	27	7.12	29.4	60	0.055	22.5	27.9	55	0.053	21.5	43	0.045	22.9	21.8	15.6
		4.30 PM	1396	27	7.14	42.7	60	0.070	22.5	40.3	58	0.068	30.8	49	0.057	23.6	15.5	16.1
		5.30 PM	1417	27	6.61	18	40	0.040	22.5	17.5	37	0.039	14.3	30	0.031	18.3	18.9	20.1
		6.30 PM	1441	27	6.71	20.2	40	0.043	22.5	19.6	38	0.042	14.8	30	0.035	24.5	21.1	16.7
29	24.03.09	3.00 PM	1441	27	6.87	115	200	0.134	27.5	113	198	0.132	95.6	160	0.119	15.4	19.2	10.3
		4.00 PM	1392	27	6.72	102	150	0.124	27.5	100	147	0.122	87.8	110	0.112	12.2	25.2	8.1
		5.00 PM	1408	27	6.75	110	150	0.130	27.5	108	147	0.129	87.4	113	0.112	19.1	23.1	12.9
		6.00 PM	1436	27	6.81	48.2	100	0.076	27.5	46.5	98	0.074	38.4	80	0.066	17.4	18.4	11.7
		7.00 PM	1481	27	6.76	52.1	100	0.080	27.5	49.9	99	0.078	39.1	78	0.066	21.6	21.2	14.7
30	25.03.09	2:00 PM	1448	27	6.53	42.2	200	0.070	27.5	40.9	195	0.068	31.4	160	0.058	23.2	17.9	15.8
		3:00 PM	1479	27	6.54	48.1	240	0.076	27.5	47.2	210	0.075	40.1	170	0.067	15.0	19.0	10.1
		4:00 PM	1467	27	6.55	45.6	280	0.073	27.5	49.9	220	0.078	34.8	140	0.062	30.3	36.4	20.9
		5:00 PM	1473	27	6.56	42.5	215	0.070	27.5	43.1	200	0.071	36.1	145	0.063	16.2	27.5	10.9
		6:00 PM	1455	27	6.57	43.1	205	0.071	27.5	47.7	185	0.076	37.2	125	0.064	22.0	32.4	14.9
31	27.03.09	2.30 PM	1479	27	6.69	59.8	130	0.087	27.5	57.4	128	0.085	46.3	102	0.074	19.3	20.3	13.1
		3.30 PM	1466	27	6.74	49.9	122	0.078	27.5	48.1	120	0.076	39.5	100	0.067	17.9	16.7	12.0
		4.30 PM	1458	27	6.78	52.4	126	0.080	27.5	51.3	125	0.079	42.2	102	0.070	17.7	18.4	11.9
		5.30 PM	1409	27	6.72	51.7	124	0.080	27.5	50.4	123	0.078	39.8	101	0.067	21.0	17.9	14.2
		6.30 PM	1435	27	6.74	53.3	125	0.081	27.5	52.8	122	0.081	43.6	102	0.071	17.4	16.4	11.7

Table A 1.7 Data for the Study on Mixing Design Parameter

Date	h (m)	Q (m3/h)	P (N.m/s)	G (s-1)	t (s)	Effective
13.09.08	0.76	1440	2913.65	1052.07	14.96	Y
22.01.09	0.76	1382	2796.29	1030.66	15.58	Y
23.01.09	0.76	1370	2772.01	1026.18	15.72	Y
24.01.09	0.76	1443	2919.72	1053.16	14.93	Y
25.01.09	0.76	1411	2854.97	1041.42	15.26	Y
10.02.09	0.76	1431	2895.44	1048.77	15.05	Y
11.02.09	0.76	1432	2897.46	1049.14	15.04	Y
14.02.09	0.76	1485	3004.70	1068.38	14.50	Y
16.02.09	0.76	1415	2863.06	1042.89	15.22	Y
17.02.09	0.76	1440	2913.65	1052.07	14.96	Y
20.02.09	0.76	1409	2850.92	1040.68	15.29	Y
01.03.09	0.76	1448	2929.84	1054.98	14.87	Y
02.03.09	0.76	1445	2923.77	1053.89	14.91	Y
03.03.09	0.76	1498	3031.00	1073.04	14.38	Y
04.03.09	0.76	1524	3083.61	1082.32	14.13	Y
06.03.09	0.76	1454	2941.98	1057.17	14.81	Y
07.03.09	0.76	1480	2994.58	1066.58	14.55	Y
08.03.09	0.76	1503	3041.12	1074.83	14.33	Y
09.03.09	0.76	1452	2937.93	1056.44	14.83	Y
11.03.09	0.76	1456	2946.02	1057.89	14.79	Y
12.03.09	0.76	1408	2848.90	1040.31	15.30	Y
13.03.09	0.76	1499	3033.03	1073.40	14.37	Y
14.03.09	0.76	1468	2970.30	1062.24	14.67	Y
15.03.09	0.76	1473	2980.42	1064.05	14.62	Y
16.03.09	0.76	1421	2875.20	1045.10	15.16	Y
20.03.09	0.76	1474	2982.44	1064.41	14.61	Y
21.03.09	0.76	1534	3103.84	1085.86	14.04	Y
22.03.09	0.76	1458	2950.07	1058.62	14.77	Y
23.03.09	0.76	1396	2824.62	1035.87	15.43	Y
24.03.09	0.76	1441	2915.67	1052.43	14.95	Y
25.03.09	0.76	1448	2929.84	1054.98	14.87	Y
27.03.09	0.76	1479	2992.56	1066.22	14.56	Y

Table A 1.8 Data for the Study on Floc Tank Design Parameter

Date	h (m)	Q (m3/h)	P (N.m/s)	G (s-1)	t (min)	GT	Effective
13.09.08	0.144	1440	552.0597	26.07	38.47	60168	Y
22.01.09	0.144	1382	529.824	25.54	40.09	61418	Y
23.01.09	0.144	1370	525.2235	25.42	40.44	61686	Y
24.01.09	0.144	1443	553.2098	26.09	38.39	60106	Y
25.01.09	0.144	1411	540.9418	25.80	39.26	60783	Y
10.02.09	0.144	1431	548.6093	25.98	38.71	60357	Y
11.02.09	0.144	1432	548.9927	25.99	38.69	60336	Y
14.02.09	0.144	1485	569.3116	26.47	37.31	59249	Y
16.02.09	0.144	1415	542.4753	25.84	39.15	60697	Y
17.02.09	0.144	1440	552.0597	26.07	38.47	60168	Y
20.02.09	0.144	1409	540.1751	25.78	39.32	60826	Y
01.03.09	0.144	1448	555.1267	26.14	38.26	60002	Y
02.03.09	0.144	1445	553.9766	26.11	38.34	60064	Y
03.03.09	0.144	1498	574.2955	26.59	36.98	58992	Y
04.03.09	0.144	1524	584.2632	26.82	36.35	58486	Y
06.03.09	0.144	1454	557.427	26.19	38.10	59878	Y
07.03.09	0.144	1480	567.3947	26.43	37.43	59349	Y
08.03.09	0.144	1503	576.2123	26.63	36.86	58894	Y
09.03.09	0.144	1452	556.6602	26.17	38.15	59919	Y
11.03.09	0.144	1456	558.1937	26.21	38.05	59837	Y
12.03.09	0.144	1408	539.7917	25.77	39.35	60848	Y
13.03.09	0.144	1499	574.6788	26.59	36.96	58972	Y
14.03.09	0.144	1468	562.7942	26.32	37.74	59592	Y
15.03.09	0.144	1473	564.7111	26.36	37.61	59490	Y
16.03.09	0.144	1421	544.7756	25.89	38.99	60569	Y
20.03.09	0.144	1474	565.0945	26.37	37.58	59470	Y
21.03.09	0.144	1534	588.0969	26.90	36.11	58295	Y
22.03.09	0.144	1458	558.9605	26.23	38.00	59796	Y
23.03.09	0.144	1396	535.1912	25.66	39.68	61109	Y
24.03.09	0.144	1441	552.4431	26.08	38.44	60147	Y
25.03.09	0.144	1448	555.1267	26.14	38.26	60002	Y
27.03.09	0.144	1479	567.0113	26.42	37.46	59370	Y

APPENDIX B

MIXING BASIN AND FLOCCULATION TANK

DESIGN CALCULATION

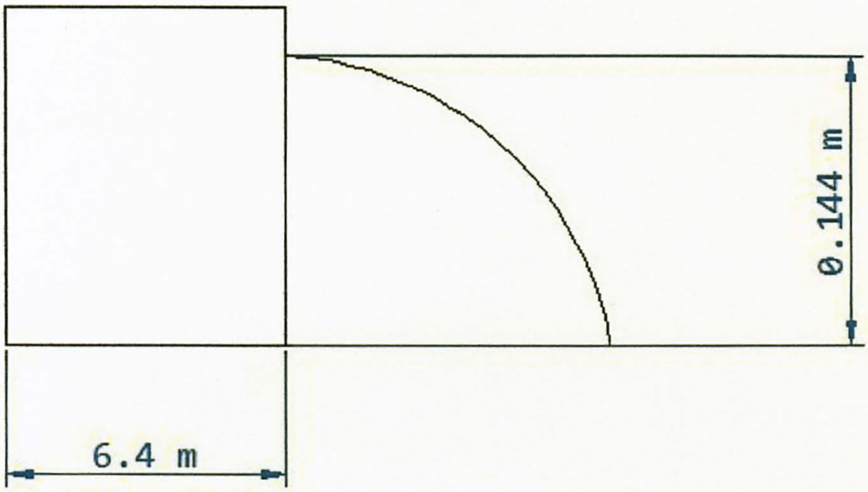
Figure B 1.1 Design Calculation Sheet for Mixing Basin

DESIGN CALCULATION SHEET NO : 1

Design Parameter of Mixing Basin

Data Obtained:

Q	1440 m^3/h
ρ	977 kgm^{-3}
g	9.81 ms^{-2}
h_f	0.76 m
μ	0.00088 $kgm^{-1}s^{-1}$



SIDE VIEW OF MIXING BASIN

Dimension of mixing basin (W x L x H) : 1.23 m x 6.4 m x 0.76 m

Power Dissipation:

$$P = Q\rho g h_f = (1440/3600)(977)(9.81)(0.76) = 2913.65\ Nm/s$$

Velocity Gradient:

$$G = \sqrt{\frac{P}{V\mu}} = \sqrt{\frac{2913.65}{(1.23)(6.4)(0.5)(0.76)(0.00088)}} = 1052.07\ s^{-1}$$

Hydraulic Retention Time:

$$t = \frac{V}{Q} = \frac{(1.23)(6.4)(0.76)}{(\frac{1440}{3600})} = 14.96\ s$$

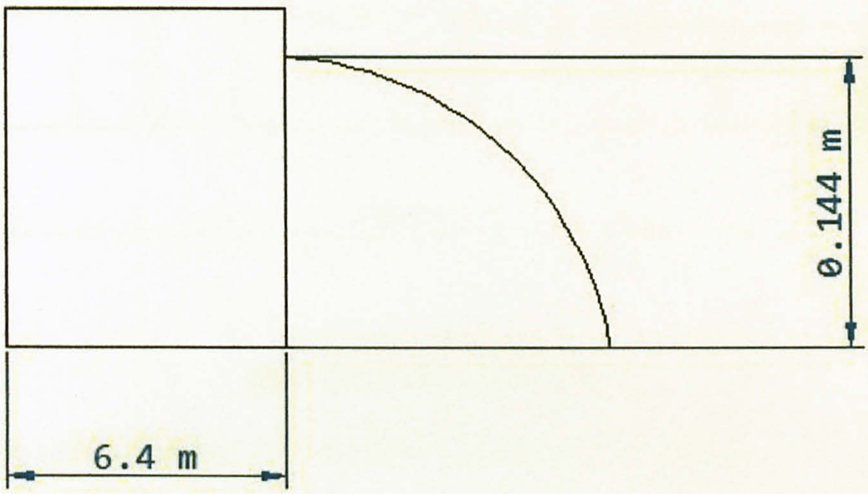
Figure B 1.2 Design Calculation Sheet for Mixing Basin

DESIGN CALCULATION SHEET NO : 2

Design Parameter of Mixing Basin

Data Obtained:

Q	1396 m^3/h
ρ	977 kgm^{-3}
g	9.81 ms^{-2}
h_f	0.76 m
μ	0.00088 $kgm^{-1}s^{-1}$



SIDE VIEW OF MIXING BASIN

Dimension of mixing basin (W x L x H) : 1.23 m x 6.4 m x 0.76 m

Power Dissipation:

$$P = Q\rho g h_f = (1396/3600)(977)(9.81)(0.76) = 2824.62\ Nm/s$$

Velocity Gradient:

$$G = \sqrt{\frac{P}{V\mu}} = \sqrt{\frac{2824.62}{(1.23)(6.4)(0.5)(0.76)(0.00088)}} = 1035.87\ s^{-1}$$

Hydraulic Retention Time:

$$t = \frac{V}{Q} = \frac{(1.23)(6.4)(0.76)}{(\frac{1396}{3600})} = 15.43\ s$$

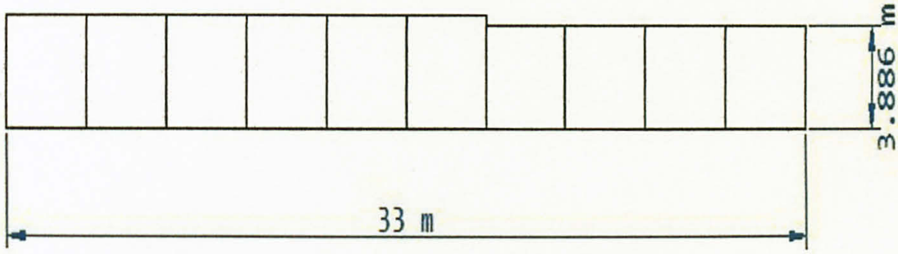
Figure B 1.3 Design Calculation Sheet for Floc Tank

DESIGN CALCULATION SHEET NO : 1

Design Parameter of Floc Tank

Data Obtained:

Q	1440 m^3/h
ρ	977 kgm^{-3}
g	9.81 ms^{-2}
h_f	0.144 m
μ	0.00088 $kgm^{-1}s^{-1}$



SIDE VIEW OF FLOC TANK

Dimension of mixing basin (W x L x H) : 7.2 m x 33 m x 3.886 m

Power Dissipation:

$$P = Q\rho g h_f = (1440/3600)(977)(9.81)(0.144) = 552.06\ Nm/s$$

Velocity Gradient:

$$G = \sqrt{\frac{P}{V\mu}} = \sqrt{\frac{552.06}{(7.2)(33)(3.886)(0.00088)}} = 26.07\ s^{-1}$$

Hydraulic Retention Time:

$$t = \frac{V}{Q} = \frac{(7.2)(33)(3.886)}{(\frac{1440}{60})} = 38.47\ min$$

Camp Number:

GT = (26.07)(38.47)(60) = 60174.774

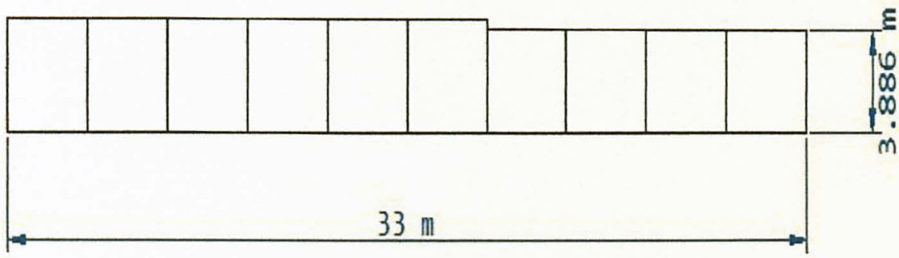
Figure B 1.4 Design Calculation Sheet for Floc Tank

DESIGN CALCULATION SHEET NO : 2

Design Parameter of Floc Tank

Data Obtained:

Q	1396 m^3/h
ρ	977 kgm^{-3}
g	9.81 ms^{-2}
h_f	0.144 m
μ	0.00088 $kgm^{-1}s^{-1}$



SIDE VIEW OF FLOC TANK

Dimension of mixing basin (W x L x H) : 7.2 m x 33 m x 3.886 m

Power Dissipation:

$$P = Q\rho gh_f = (1396/3600)(977)(9.81)(0.144) = 535.19\ Nm/s$$

Velocity Gradient:

$$G = \sqrt{\frac{P}{V\mu}} = \sqrt{\frac{535.19}{(7.2)(33)(3.886)(0.00088)}} = 25.66\ s^{-1}$$

Hydraulic Retention Time:

$$t = \frac{V}{Q} = \frac{(7.2)(33)(3.886)}{(\frac{1396}{60})} = 39.68\ min$$

Camp Number:

GT = (25.66)(39.68)(60) = 61091.328

APPENDIX C

MIXING BASIN AND FLOCCULATION TANK

TECHNICAL DRAWING

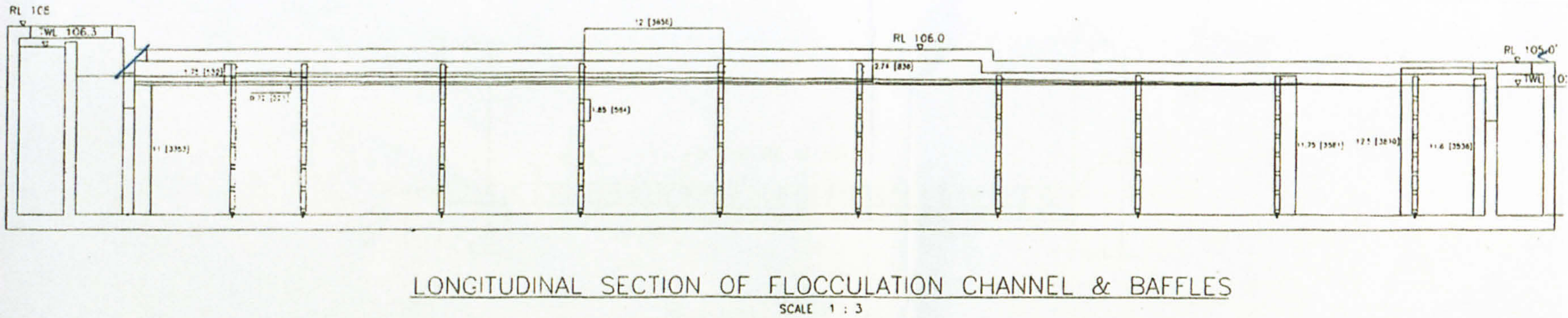


Figure C.1 Longitudinal Section of Flocculation Channel & Baffles

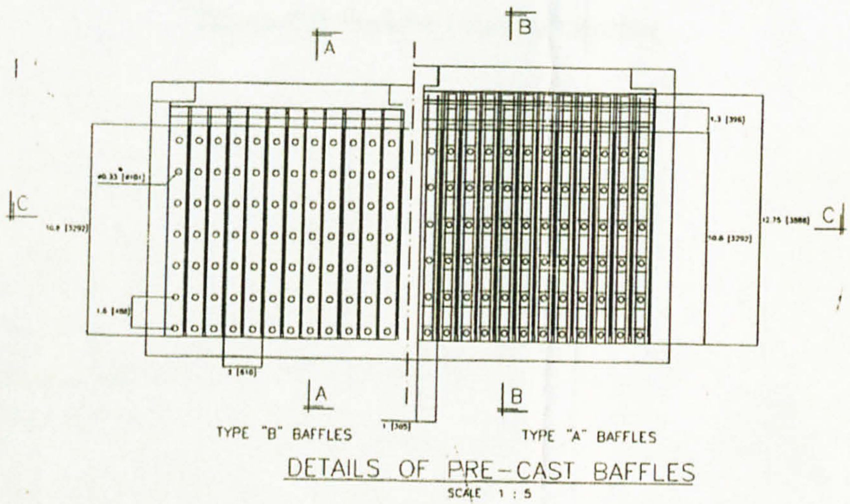


Figure C.2 Details of Pre-cast Baffles

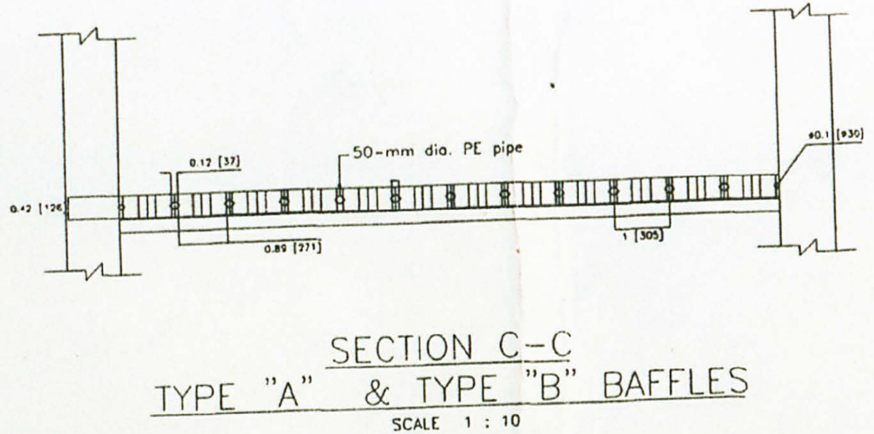


Figure C.3 Type "A" and "B" Baffles

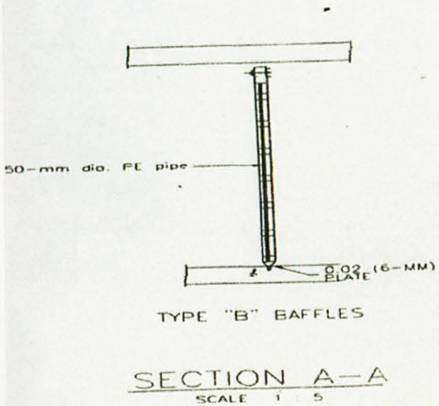


Figure C.4 Section A-A Side Elevation

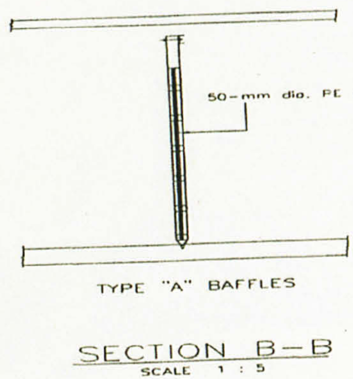


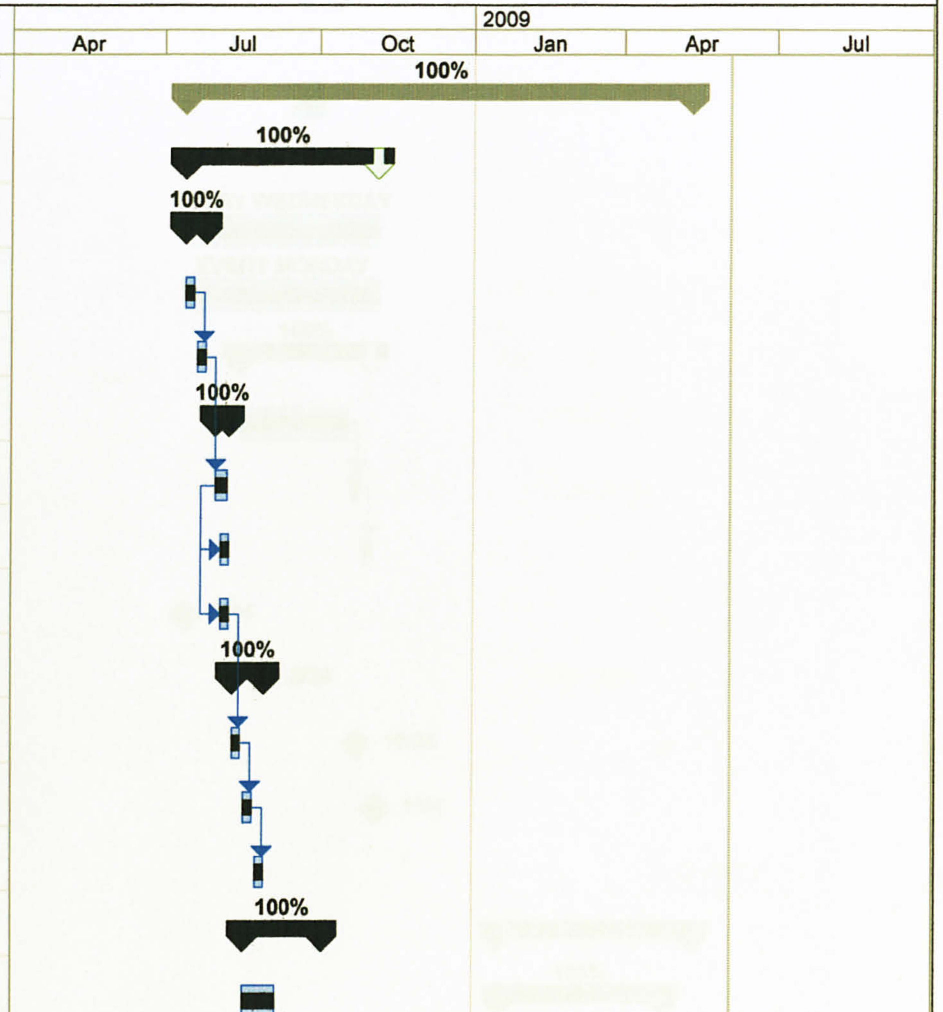
Figure C.5 Section B-B Side Elevation

APPENDIX D

GANTT CHART

Final Year Project Gant Chart

ID	Task Name	Duration	Start	% Complete	Finish
0	**Gant Chart FYP**	**214.88 days?**	**Mon 7/14/08**	**100%**	**Mon 5/11/09**
1	**FYP 1**	**82 days?**	**Mon 7/14/08**	**100%**	**Tue 11/4/08**
2	**Proposal**	**10 days?**	**Mon 7/14/08**	**100%**	**Fri 7/25/08**
3	Initiate	5 days	Mon 7/14/08	100%	Fri 7/18/08
4	Acceptance	5 days?	Mon 7/21/08	100%	Fri 7/25/08
5	**Prelim Research Work**	**6 days?**	**Fri 8/1/08**	**100%**	**Fri 8/8/08**
6	Objective	5 days?	Fri 8/1/08	100%	Thu 8/7/08
7	Scope of Work	5 days?	Mon 8/4/08	100%	Fri 8/8/08
8	Problems Statement	5 days?	Mon 8/4/08	100%	Fri 8/8/08
9	**Literature**	**15 days?**	**Mon 8/11/08**	**100%**	**Fri 8/29/08**
10	Preliminary	5 days?	Mon 8/11/08	100%	Fri 8/15/08
11	Supplementary	5 days?	Mon 8/18/08	100%	Fri 8/22/08
12	Analysis	5 days	Mon 8/25/08	100%	Fri 8/29/08
13	**Seminar**	**35 days?**	**Mon 8/18/08**	**100%**	**Fri 10/3/08**
14	Optional	15 days?	Mon 8/18/08	100%	Fri 9/5/08

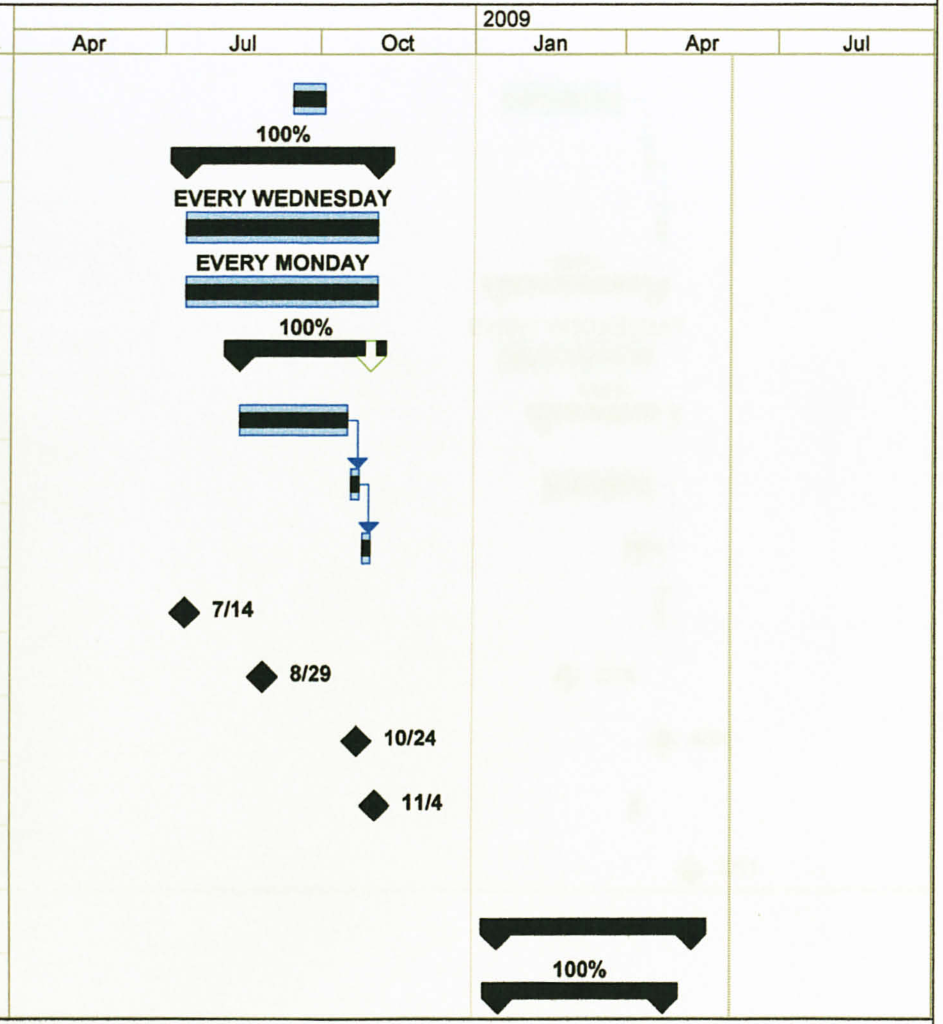


Project: Gant Chart FYP
Date: Wed 6/3/09

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Final Year Project Gant Chart

ID	Task Name	Duration	Start	% Complete	Finish
15	Compulsory	15 days?	Mon 9/15/08	100%	Fri 10/3/08
16	**Meeting**	**82 days**	**Mon 7/14/08**	**100%**	**Tue 11/4/08**
17	Supervisor	82 days	Mon 7/14/08	100%	Tue 11/4/08
18	Coordinator	82 days	Mon 7/14/08	100%	Tue 11/4/08
19	**Field Data**	**56 days?**	**Fri 8/15/08**	**100%**	**Fri 10/31/08**
20	Prelim Data Collection	46 days?	Fri 8/15/08	100%	Fri 10/17/08
21	Supplementary Data Collection	5 days	Mon 10/20/08	100%	Fri 10/24/08
22	Analysis	5 days	Mon 10/27/08	100%	Fri 10/31/08
23	**Literature Review**	1 day	Mon 7/14/08	100%	Mon 7/14/08
24	**Progress 1**	1 day	Fri 8/29/08	100%	Fri 8/29/08
25	**Interim**	1 day	Fri 10/24/08	100%	Fri 10/24/08
26	**Oral**	1 day	Tue 11/4/08	100%	Tue 11/4/08
27					
28	**FYP 2**	**81 days**	**Thu 1/15/09**	**100%**	**Mon 5/11/09**
29	**Literature**	**69 days**	**Fri 1/16/09**	**100%**	**Fri 4/24/09**

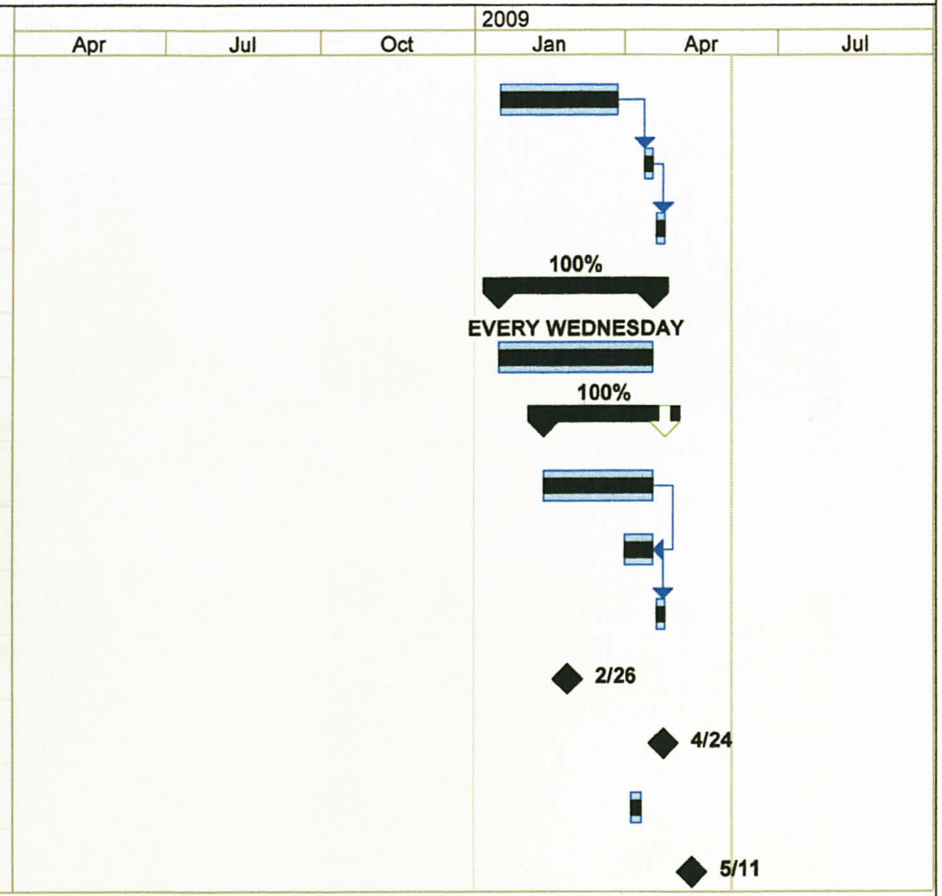


Project: Gant Chart FYP
Date: Wed 6/3/09

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

Final Year Project Gant Chart

ID	Task Name	Duration	Start	% Complete	Finish
30	Preliminary	50 days	Fri 1/16/09	100%	Fri 3/27/09
31	Supplementary	5 days	Mon 4/13/09	100%	Fri 4/17/09
32	Analysis	5 days	Mon 4/20/09	100%	Fri 4/24/09
33	**Meeting**	**65 days**	**Thu 1/15/09**	**100%**	**Fri 4/17/09**
34	Supervisor	65 days	Thu 1/15/09	100%	Fri 4/17/09
35	**Field Data**	**51 days**	**Wed 2/11/09**	**100%**	**Fri 4/24/09**
36	Prelim Data Collection	46 days	Wed 2/11/09	100%	Fri 4/17/09
37	Supplementary Data Collection	13 days	Wed 4/1/09	100%	Fri 4/17/09
38	Analysis	5 days	Mon 4/20/09	100%	Fri 4/24/09
39	**Progress 2**	1 day	Thu 2/26/09	100%	Thu 2/26/09
40	**Disertation**	1 day	Fri 4/24/09	100%	Fri 4/24/09
41	**Poster**	5 days	Sun 4/5/09	100%	Fri 4/10/09
42	**Oral**	1 day	Mon 5/11/09	100%	Mon 5/11/09



Project: Gant Chart FYP
Date: Wed 6/3/09

APPENDIX E

MIXING BASIN AND FLOCCULATION TANK

PHOTO

Figure E.1 Sungai Kampar

Figure E.2 Sungai Dipang

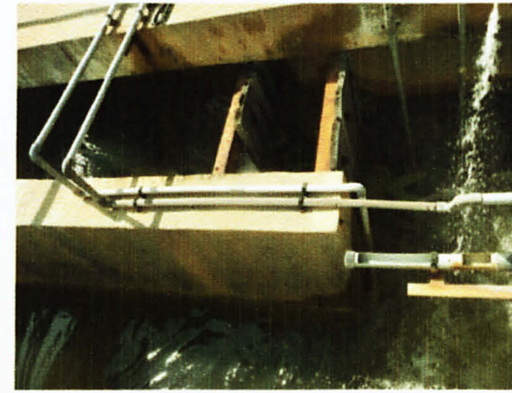


Figure E.3 Mixing Basin

(a)

(b)

(c)

Figure E.4 (a), (b), (c) Flocculation Tank